CABBAGE LOOPER, SOYBEAN LOOPER, AND TOBACCO BUDWORM POPULATIONS NEAR QUINCY, FLORIDA: SEASONAL ABUNDANCE, HOST PREFERENCE, AND SUPPRESSION BY NATURAL ENEMIES

By

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A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF
THE UNIVERSITY OF FLORIDA
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1976

ACKNOWLEDGMENTS

Many have assisted in the construction of this dissertation and I am grateful to them. Dr. P. D. Lingren brought me to Florida and this research, and was always eager to help as an advisor, prodder, and friend. Dr. R. I. Sailer, who served as committee chairman, was generous in yielding time to assist with problems concerning my research, course work, writing and other matters. Dr. G. L. Greene was helpful with his constructive criticism and guidance, and helped in obtaining work space, equipment, and materials. Drs. W. H. Whitcomb and J. Reiskind helped very much with their advice, guidance, criticism, and other assistance.

I am thankful for my wife, Betsy, who has been tolerant, patient, and encouraging. In addition, she assisted as technician, collator, typist, and proofreader.

Without the training received from my father and mother, I would never have completed this work. And Mr. L. C. Martin, Dr. Joseph Schaffner, and Dr. R. L. Ridgway were the most important individuals in initiating my pursuit of knowledge in entomology.

The major support (financial and otherwise) came as a result of a cooperative effort of the Southern Region, Agr. Res. Serv., USDA, Quincy, FL location, and the Agr. Res. and Educ. Center, IFAS, Quincy, FL (Cooperative Agreement no. 12-14-100-10, 914(33)). Assistance was also provided by the Dep. of Entomol. and Nematol., Univ. of Florida, and by Peggie Martin and Associates, Inc., Pearsall, TX, in the last few months of work on this dissertation.

The development of the research presented herein depended greatly on the taxonomic assistance (with collected specimens) by E. E. Grissell, Div. Plant Industry, Gainesville, FL, P. M. Marsh, C. F. W. Muesebeck, and R. W. Carlson, Systematic Entomol. Laboratory, Beltsville, MD (Hymenoptera); C. Tauber, Cornell Univ., Ithaca, NY (Neuroptera); L. R. Ertle, Agr. Res. Serv., USDA, Newark, DE, and S. Nagarkatti, CIBC, Bangalore, India (egg parasitoids); F. W. Mead, Div. Plant Industry, and R. I. Sailer, Univ. of Florida (Hemiptera); R. E. Waites, Univ. of Florida, and R. D. Gordon, Systematic Entomol. Laboratory (coccinellids); W. H. Whitcomb, Univ. of Florida (predaceous arthropods); B. Puttler, D. L. Hostetter, C. M. Ignoffo, and R. E. Pinnell, North Central Region, Agr. Res. Serv., USDA, Columbia, MO, (parasitoids and pathogens); H. V. Weems, Div. Plant Industry, and C. W. Sabrosky, Systematic Entomol. Laboratory (tachinids); and R. E. Woodruff, Div. Plant Industry (Coleoptera).

Insects provided by A. H. Baumhover, Southern Region, Agr. Res. Serv., USDA, Oxford, NC, and R. K. Morrison and R. E. Kinzer, Southern Region, Agr. Res. Serv., USDA, College Station, TX, and planting material furnished by W. B. Tappan and R. L. Stanley, Agr. Res. and Educ. Center, Quincy, FL, are appreciated. Work space provided by D. Davis and T. Newsome, Southern Region, Agr. Res. Serv., USDA, Gainesville, FL, is gratefully ackrowledged.

Especially helpful in providing information, assistance, and/or suggestions were W. G. Eden, W. H. Chapman, V. Perry, D. Fish, R. Crocker, G. D. Butler, Jr., J. O. Strandberg, and N. Leppla. Typists and technicians who were most helpful with this research included P. Whitehurst, A. Brown, T. Bowers, J. T. Suber, W. R. van Landingham, G. Wingfield, B. Spires, and J. Walden.

I am very grateful to L. C. Martin, O. Doyal, and H. Hernandez for their patience in the final months of my completion of this dissertation.

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Abstract of Dissertation Presented to the Graduate Council
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

CABBAGE LOOPER, SOYBEAN LOOPER, AND TOBACCO BUDWORM POPULATIONS NEAR QUINCY, FLORIDA: SEASONAL ABUNDANCE, HOST PREFERENCE, AND SUPPRESSION BY NATURAL ENEMIES

By

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March, 1976

Chairman: Dr. R. I. Sailer
Co-Chairman: Dr. G. L. Greene
Major Department: Entomology and Nematology

Population dynamics of the cabbage looper, Trichoplusia ni (Hübner), the soybean looper, Pseudoplusia includens (Walker), and the tobacco budworm, Heliothis virescens (F.), were investigated in an 8-acre cropping system, including tobacco, soybeans, and 18 other crops, and in some additional study areas. Discovery of critical factors influencing interaction between host and natural enemy populations was the primary research objective. Results should aid in developing management practices designed to minimize economic losses caused by these pests.

Cabbage looper was found during most months in its most utilized host, collards, and reached highest densities in May, June, and September. Collards and cabbage were preferred hosts. Also, catches in pheromone-baited blacklight and grid traps were positively correlated to number of immatures in the field during 1 year.

Soybean looper was found on its preferred host, soybeans, and a few other hosts, at much lower densities than cabbage looper. It

occurred in the system from June to October. Blacklight trap catches were indicative of immatures of soybean looper in the field.

Tobacco budworms occurred in the system from early or mid-April through October in several wild hosts, in white clover, tomatoes, tobacco, and okra. Tobacco was the preferred host. Densities of this pest within the system were similar to those of the cabbage looper. Prediction of these densities of tobacco budworm immatures by utilizing data from adult traps appeared promising.

Copidosoma truncatellum (Dalman), Meteorus autographae Muesebeck, and Voria ruralis Fallén were the most important larval parasitoids recovered from cabbage loopers; Trichogramma spp. was by far the major egg parasitoid. Parasitization of eggs and larvae in crucifers ranged from 0 to 55% and 0 to 100%, respectively, and was generally highest during the spring and fall. Parasitization of cabbage looper immatures was generally highest in tomatoes. Larval populations of cabbage looper were decimated by nuclear polyhedrosis virus after reaching high densities in the summer.

The parasitoid complex for the soybean looper was similar to that for the cabbage looper. Parasitization of soybean looper larvae was generally high but eggs in soybeans were seldom attacked. Larvae were seldom diseased; however, the most frequent pathogen was Nomuraea sp.

Tobacco budworm eggs were rarely parasitized in tobacco, but were frequently parasitized in tomatoes and okra. Parasitization of tobacco budworm larvae in tobacco was usually over 50% and was mostly by Cardiochiles nigriceps Viereck. Incidence of disease, even during high densities of tobacco budworm larvae, was low to moderate.

The primary predaceous arthropods associated with the cabbage looper and tobacco budworm were Coleomegilla maculata (DeGeer) and Hippodamia convergens (Guérin-Méneville). Geocoris punctipes (Say) was the most prevalent predator in soybeans, although several other predaceous arthropods were also numerous in this host of the soybean looper. White clover was the most important reservoir of predaceous arthropods, although corn, sorghum, millet, and some other crops were also quite important as sources of predators.

Cabbage loopers in crucifers and tobacco budworms in tobacco were probably not substantially suppressed by predaceous arthropods. However, soybean loopers in soybeans and tobacco budworms in white clover and okra were apparently suppressed to low to moderate densities by these entomophages.

Three supplemental releases of ca. 230,000 female Trichogramma pretiosum Riley per acre at 3-day intervals were an effective suppressant of the 3 noctuids on tomatoes, soybeans, collards, and other crops, but not on tobacco. Under conditions of the experiment, 3 releases of ca. 194,000 larvae of Chrysopa carnea Stephens per acre/release at weekly intervals were not effective against the 3 noctuids in any crops tested.

SECTION I

INTRODUCTION

An understanding of the intra- and inter-specific relationships in artificial supraorganismal systems and surrounding "natural" communities is critical to effective applied control of organisms within these systems (Allee et al. 1949). This is essentially the community concept as outlined by Odum (1959) -- if man deems it necessary to suppress a particular organism he will cause less disruption and suffer fewer detrimental consequences if he intelligently modifies the community instead of making a direct attack on the organism without regard to community consequences.

The research reported herein was an investigation of the relationships of three noctuids, the cabbage looper, Trichoplusia ni (Hübner), the soybean looper, Pseudoplusia includens (Walker), and the tobacco budworm, Heliothis virescens (F.), and their natural enemies, in a relatively simple system of crops, and in the absence of applied control. Additional knowledge of relationships of these insect pests, and the entomophagous organisms and crops associated with them, should help provide insight into means for more effectively regulating and suppressing these 3 often economically injurious pests.

A primary objective was to find vulnerable areas in the 3 pests' population cycles that might be exploited in suppressive manipulations designed to maintain these pests at tolerable levels in tobacco, soybeans, and other crops. Hopefully such knowledge will aid crop (or systems)

managers in developing more suitable means of control utilizing methods compatible with the community concept.

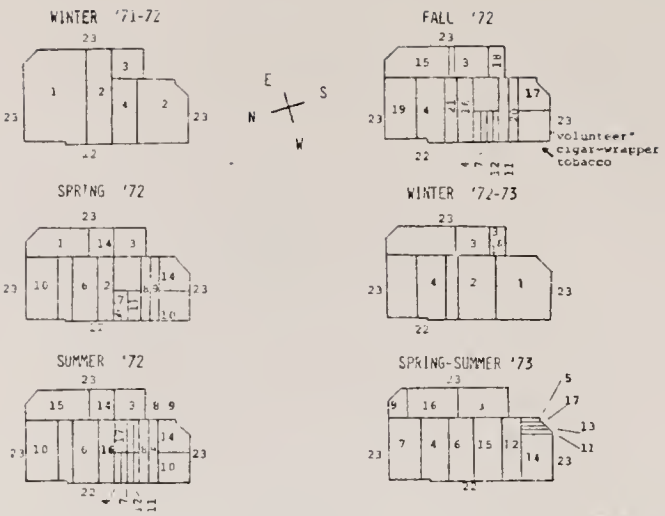
General Methods and Materials

Eight-Acre Cropping System

A sequence of crops involving ca. 0.1-1.0 acre of collards, 0.6-0.9 acre of white clover (relatively "permanent" crops), 1.7 acre of cigar-wrapper tobacco, 1.0 acre of flue-cured tobacco, 0.9-1.1 acre of soybeans, ca. 0.1 acre of cabbage, 0.1-0.5 acre of okra, 0.1-1.1 acre of tomatoes, 0.9-1.0 acre of field corn, ca. 0.1 acre of sweet corn, ca. 0.1-0.3 of sorghum, 0.6-0.9 acre of millet, ca. 0.1-0.5 acre of southern field peas, ca. 0.1 acre of bell peppers, ca. 0.1-0.6 acre of peanuts, 1.1 acre bush beans, 0.3 acre of squash, 0.5 acre of turnips, 0.3 acre of pumpkins, 2.2-3.3 acre of rye, and 1.4-3.2 acre of wheat, were grown on ca. 8 acres in an old tobacco shade (Kincaid 1960) that had not been used for several years. The 8-acre cropping system was located ca. 6 mi south of Quincy, Florida (Fig. 1).

The cigar-wrapper tobacco in the system was covered with loosely woven cloth ("cheese cloth") of 8 x 10 threads per in.^{2} The sorghums were grain sorghums in 1972 and a forage sorghum in 1973. Bahia grass was on ca. 7 acres immediately surrounding the northeast, southeast, and southwest sides of the system. Wild hosts occurring along a road were present on the northwest side of the system (Fig. 1).

Of all the crops in the system, collards, flue-cured tobacco, field corn, sweet corn, sorghum, bush beans, squash, turnips, pumpkins, field peas, rye, and wheat were generally in the best growing condition. However, many collard plants did become diseased in July and August of 1972.



NO.	CROP (VARIETY)	NO. ROWS /16 FT	PERIOD IN SYSTEM
1.	RYE (WESER)	DRILLED	
2.	WHEAT (WAKELAND)	DRILLED	
3.	WHITE CLOVER (LA S-1, REGAL)	BROAD-CASTED	
4.	COLLARDS (VATES)	4&5	
5.	CABBAGE (EARLY ROUND DUTCH)	4	
6.	FLUE-CURED TOBACCO (COKER 298)	4	
7.	TOMATOES (HOMESTEAD)	4	
8.	SWEET CORN (SILVER QUEEN, GOLDCREST, IOANA)	5	
9.	SORGHUM (DEKALB BR-64, SAVANNAH--1972, FUNKS 102F--1973)	5& BROAD-CASTED	
10.	CIGAR-WRAPPER TOBACCO (FL-17)	4	
11.	BELL PEPPER (WORLD BEATER, KEYSTONE RESISTANT GIANT-3)	4	
12.	OKRA (LONG POD GREEN)	4	
13.	PEANUTS (TIFSPAN SPANISH RUNNER)	4	
14.	FIELD CORN (COKER 71, PIONEER 3369A)	4	
15.	SOYBEANS (BRAGG)	4	
16.	MILLET (STAR PEARL)	BROAD-CASTED	
17.	SOUTHERN FIELD PEAS (CREAM 40, CA NO.5 BLACKEYES)	4	
18.	PUMPKINS (12 VARIETIES, INCLUDING BIG MAX AND KING OF MAMMOTHS)	HILLED	
19.	BUSH BEANS (7 VARIETIES, MOSTLY ASTRO)	4	
20.	SQUASH (EARLY WHITE SCALLOPS)	4	
21.	TURNIPS (PURPLE TOP)	4	
22.	WILD HOSTS		
23.	BAHIA GRASS		

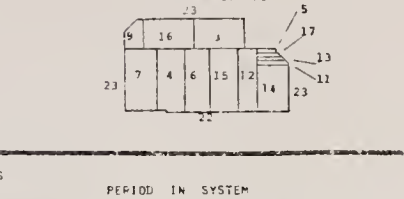


Fig. 1.--Crop rotation within an 8-acre cropping system near Quincy, FL.

The other crops were also generally in good condition during much of the study period, but at times were of a thin stand, drought-stressed, weedy, or diseased. Much of the white clover top growth died during July and August of 1972, but it was lush again in September. The 1972 fall "volunteer" crop of cigar-wrapper tobacco was poor, consisting of < 100 tobacco plants on 1/2 acre. As a result, this "crop" consisted mostly of wild hosts. Similarly I obtained a poor stand in the fall planting of tomatoes in 1972 and there were < 1000 plants per acre. I also had trouble in obtaining a thick stand of millet in 1973; therefore, it was quite sparse relative to the 1972 crop. Thorny pigweed, Amaranthus spinosus, was not kept under control in the 1973 crop of tomatoes, peanuts, and bell peppers. In addition to the weed problem, the 1973 crop of bell peppers also became diseased, and much fruit rotted.

The crops selected for the 8-acre cropping system were mostly those normally grown in fields and gardens in the northern Florida area, except for grain sorghum and pumpkins. Soybeans and cigar-wrapper tobacco have been important commercial field crops in the Quincy area and collards have been common in gardens.

Crops were generally grown during periods in which they are commonly grown in northern Florida. Production practices were similar to those of an average farmer or gardener, except that no commercial chemical insecticides, nematicides, or fungicides were used. A ton per acre of dolomitic lime was, however, applied in the winter of 1972. Also, all crops except white clover were fertilized with inorganic fertilizer, and a herbicide program was followed in many crops. Generally 40-80 lb of nitrogen and 40-120 lb of phosphoric acid and potash were applied to

the various crops, with tobacco[1] and tomatoes receiving the heaviest applications. Tobacco, corn,[2] and grain sorghum were also side-dressed with 40-120 lb of nitrogen when they were 1-2 ft in height. Collards, cabbage (in 1973), soybeans, okra, tomatoes, field peas, bell peppers, peanuts, and bush beans, were given a pre-emergence treatment of 0.5-1.0 lb (AI per acre) trifluralin; tobacco was given a pre-emergence treatment of 0.75 lb (AI per acre) benefin; squash was given a pre-emergence treatment of 0.5 lb (AI per acre) nitralin; and cabbage (in 1972) was given a post-emergence treatment of 2.0 lb (AI per acre) of alachlor. Crops were usually irrigated from an overhead sprinkler system when necessary in order to follow "normal" crop production practices. Tobacco was irrigated more frequently than other crops.

Crops were removed from the system by mowing (i.e., rye, wheat, cabbage (in 1972), tobacco, corn, grain sorghum, okra, and millet) and/or turning them under with an offset disc harrow. Some fruit were harvested in some crops (e.g. okra) to prevent termination of growth. Also blooms were topped 2-3 times per crop in tobacco and collards.

Of the immediate area (i.e., ca. 3 miles) surrounding the 8-acre cropping system, about half was forested. Another large portion was covered with volunteer vegetation, bahia grass, rye, or millet during my studies in the system. However, there were also 2 cigar-wrapper tobacco shades ca. 1/2 mile from the 8-acre system, which did contain a total of ca. 20 acres of tobacco during both 1972 and 1973. Also more than 100 acres of soybeans were growing 1-2 miles from the system, a small

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[1] "Tobacco" will be used when referring to both flue-cured and cigar-wrapper tobacco.

[2] "Corn" will be used when referring to both field corn and sweet corn.

garden possessing collards was located within 200 ft of the system, and there were several patches of field corn within 2 miles of the system.

Whole plant inspections, sweeps, and plant shakes

The 8-acre cropping system was primarily monitored for eggs, larvae, and/or adults of Plusiinae and Heliothis spp., as well as by certain other pest species, and predaceous arthropods, by inspecting the whole portion of the plants above the ground in 3 to six 0.001-acre sections of row (10.9 or 13.6 row-ft) in most crops. Plants were generally inspected 1-2 times a week; during several weeks more samples were taken in some crops. In broadcast or drilled crops (white clover, rye, wheat, millet, and sorghum (in 1973)), whole plant inspections were made on 0.00025 acre sections (1 ft x 10.9 ft). Samples were taken in a diagonal pattern across each crop.

Sweeps with a net, 15 inches in diameter, were also used as a sampling device in white clover, rye, wheat, millet, sorghum, and occasionally in other crops. These samples usually consisted of 3-6 replicates of 25 sweeps. In soybeans, some samples from the standing crop were shaken onto a cloth between the rows (Boyer and Dumas 1963). These were similar in replication and size to whole plant inspections. On a few dates in the fall of 1973, counts of insects per plant were taken on the sparsely populated stands of cigar-wrapper tobacco and tomatoes.

Sampling was initiated shortly after a good stand of the crop emerged and was usually continued weekly until the crop was destroyed. However, pumpkins were only sampled during 2 weeks (September 10 and 24). Also samples from white clover, rye, wheat, and millet in 1972 were mostly taken with the sweep net.

Collections of immatures

Eggs and larvae of Plusiinae, Heliothis spp., and various other insects were collected in whole plant inspections, sweeps, plant shakes, and some additional searches in the 8-acre cropping system. Eggs of various pest species were collected on masking tape while taking whole plant inspections, and trapped with transparent tape within holes in cardboard paper by the method described by Hoffman et al. (1970). Larvae were also collected, and were placed on a synthetic cabbage looper (modified from Henneberry and Kishaba(1966)) or tobacco budworm (modified from Berger 1963) diet contained in a 4-dr clear, paper-capped, plastic cup.

Estimates of individual larval size were made in the field. "Small" larvae were ca. <0.4 in. (or <1 cm), "medium" larvae were ca. 0.4-0.8 in. (or 1-2 cm), and "large" larvae ca. >0.8 in. (or >2 cm).

Larvae of Heliothis spp. were identified to species in the laboratory at some time after they reached the 3rd instar. Plusiinae were identified only after they became adults.

Even though all eggs (Peterson 1964) and larvae (Crumb 1956) were determined to be Plusiinae, Heliothis spp., or otherwise, no eggs were positively identified to species; and, many larvae of Heliothis spp., and all larvae of Plusiinae that were parasitized or diseased, were not positively identified to species. In most of the crops in which cabbage loopers, soybean loopers, and tobacco budworms were found, almost all the larvae or adults of these pests which were collected and identified, belonged to only 1 Plusiinae species or 1 Heliothis species. Therefore, when eggs or larvae are discussed in the various sections of this thesis,

they are usually labeled as the major species found in the crop, with qualifications made when necessary.

D-vac samples

In addition to the counts in the field, predaceous species were sampled weekly from ca. 0.01 acre in triplicate (sometimes more) from each crop in the 8-acre cropping system and from wild hosts in or adjacent to the system with a suction sampler (D-vac®) similar to the one described by Detrick (1961), and then were counted in the laboratory. One-hundredth of an acre was 109 row-ft for crops with 4 rows per 16 ft, 136 row-ft for crops with 5 rows per 16 ft, and 2 x 219 ft in broadcasted and drilled crops (see Fig. 1). Arthropods captured during the D-vac sampling were retained in nylon organdy bags, placed in ice chests, transported to the laboratory, and processed through Tullgren funnels. In 1972 all crops of the 8-acre cropping system were sampled in this manner. However, in 1973, cabbage, peanuts, field peas, and bell peppers were not sampled with the D-vac.

Wild Hosts

In addition to D-vac sampling, other methods were used to sample wild hosts growing on roadsides, as well as some near and within the 8-acre cropping system. Most samples were obtained during the fall of 1972 and spring and summer of 1973. Sampling was primarily with a sweep net but some random inspections of plants were also made. All larvae and eggs of Plusiinae and Heliothis spp. found were collected and handled as previously described.

The complex of volunteer plants sampled consisted primarily of dog fennel, Eupatorium spp.; ragweed, Ambrosia artemisiifolia; prickly sida,

Sida spinosa; crimson clover, Trifolium incarnatum; and various grasses (probably mostly bahia grass) in the roadside area adjacent to the system; and thorny pigweed, crabgrass, Digitoria spp.; and nutsedge, Cyperus spp. within the system. Some other wild hosts from which samples were taken were hop clover, Medicago lupulina; sicklepod, Cassia obtusifolia; camphor plant, Heterotheca subaxilaris; goldenrod, Solidago spp.; pepper grass, Lepidium virginicum; toadflax, Linaria canadensis; dock, Rumex hastatulus; crotolaria, Crotalaria sp.; johnsongrass, Sorghum helepense; kudzu, Pueraria lobata; cocklebur, Xanthium pennsylvanicum; beggarweed, Desmodium tortuosum; smallflower morningglory, Jaquemonta taminifolia; Venus lookingglass, Specularia perfoliata; and vervain, Verbena tenuisecta.

One-Acre Shade

Additional experiments were conducted in a 1-acre cigar-wrapper tobacco shade (232 x 192 x 9 ft) covered with loosely woven cotton cloth of 8 x 10 threads per in.^{2}, except for several holes in the ceiling cloth which could not be patched. 'Astro' bush beans, 'Florida 20' cigar-wrapper tobacco, 'Hampton' soybeans, 'Vates' collards, 'Early Round Dutch' cabbage, 'World Beater' bell peppers, and 'Homestead' tomatoes were planted (Table 1) in 5 to ten 200-ft rows spaced 3 ft apart from center (Fig. 2).

Visual inspections during the experiment for amount of foliage and extent of insect, disease, and weed damage to the crops, indicated cabbage and tobacco were in the poorest condition. The foliage of soybeans was in the best condition followed by bell peppers, bush beans, collards, and tomatoes. It was necessary to apply a short residual insecticide, mevinphos, at 1.5 lb AI per acre, to prevent extensive insect damage to

Table 1.--Schedule of cultural practices and of releases of cabbage looper, soybean looper, and tobacco budworm in a 1-acre tobacco shade, Quincy, FL, July-September, 1971.

Date	Crop treatment	Rate/acre	Crop
	Cultural practices		
Jun. 23	Planting (Seedlings)	-	Bell pepper, tomato
July 1	Planting (Seeds)	-	Soybean
Jul. 6,7	Planting (Seedlings)	-	Collard, cabbage, cigar-wrapper tobacco
Jul. 10	Planting (Seedlings)	-	
Aug. 3	Fertilizer - 6-12-12 and 36-0-0	1000 lb and 50 lb	Bell pepper, tomato, collard, cabbage, cigar-wrapper tobacco, bush bean
	Fertilizer - 6-12-12	200 lb	Soybean
	Cultivation	-	All crops
Aug. 5	Herbicide - DCPA	10 lb	Bell pepper, tomato, collard, cabbage
Aug. 6	Insecticide - Mevinphos	1.5 lb	All crops
	Moth releases[a]		
Aug. 15	Tobacco budworm	30	All crops
	Cabbage looper	30	" "
Aug. 19	Tobacco budworm	82	" "
Aug. 20	Tobacco budworm	30	" "
	Cabbage looper	30	" "
Aug. 25	Tobacco budworm	30	" "
	Cabbage looper	30	" "
Aug. 31	Soybean looper	100	" "
Sep. 1	Tobacco budworm	350	" "
Sep. 8	Soybean looper	100	" "

[a]Adult ♂ and ♀ pairs (1-3 days old).

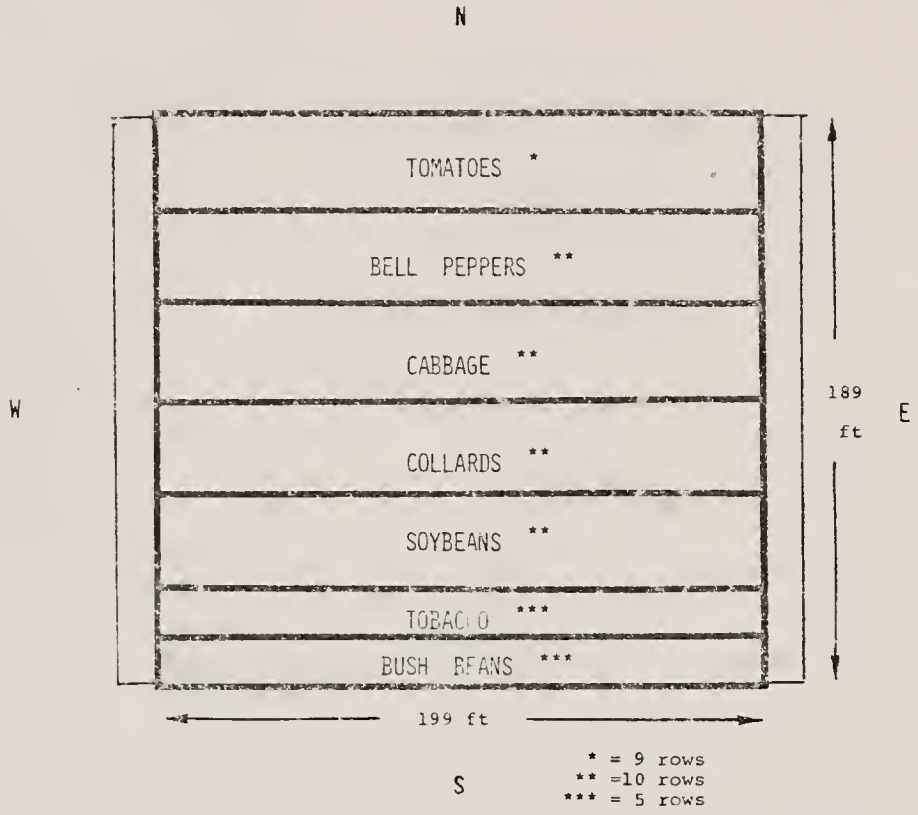

Fig. 2.--Crop layout in a 1-acre tobacco shade, Quincy, FL, July - September, 1971.

the crops prior to beginning the experiment (Table 1), and in August a pathogen caused "black rot" in the developing heads of cabbage. Also, the tomato plots became infested with thorny pigweed.

The area immediately surrounding the shade was covered with volunteer vegetation. Also there were several other cigar-wrapper tobacco shades containing tobacco near the 1-acre shade.

Numbers of eggs and larvae of Plusiinae, Heliothis spp., and several other insect groups were estimated in each crop from 5 to 10 whole-plant-inspection samples in 5- to 10-ft sections of row in all crops except cigar-wrapper tobacco. On cigar-wrapper tobacco, samples were always made twice as large (10- to 20-ft sections of row) as those in other crops because of the sparse stand.

Eggs and larvae of lepidopterous species were collected and identified as was described for the 8-acre cropping system except that only tobacco budworm diet was used. Eggs, and parasitized or diseased larvae of some Heliothis spp. and all Plusiinae, were not positively identified to species. Therefore, as in the 8-acre cropping system, names used in discussion of those groups in the Trichogramma pretiosum (Riley) and Chrysopa carnea Stephens release sections are those of the major groups known to be present based on identified samples.

Two hundred row-ft were sampled with a D-vac in each crop for an additional monitor on predaceous arthropod populations. Techniques used were similar to those previously described for D-vac sampling.

Data on weather conditions prevailing during the periods of observation in the 1-acre shade, and the 8-acre cropping system, were obtained from the weather station of the National Weather Service, NOAA, located at the Agricultural Research and Education Center, IFAS, Quincy, FL.

SECTION II

SEASONAL ABUNDANCE AND HOST PREFERENCE

Knowledge of seasonal abundance of pests such as the cabbage looper, soybean looper, and tobacco budworm, in the various areas where they occur, is fundamental to developing an understanding of the population dynamics of these pests (Anonymous 1969). Methods for predicting economic infestations of these pests, and schemes for subsequent manipulations to limit their densities can not be developed and/or perfected until such information is obtained.

Thus, information on seasonal abundance of the 3 noctuids should allow better employment of existing technology for prediction, prevention, and suppression of potentially damaging infestations, as well as stimulate development of new mechanisms for prediction, prevention, and suppression.

Host preferences of a particular pest and the availability of suitable and preferred hosts are intricately related to the seasonal abundance characteristics of the pest. Although the cabbage looper, soybean looper, and tobacco budworm appear to prefer certain hosts, infestations in crops other than their "namesake," or other common hosts, occur quite frequently. For instance, for the period of 1970-1972 cabbage looper infestations were reported in tobacco, soybeans, tomatoes, bell peppers, bush beans, southern field peas, turnips, spinach, celery, cantaloupe, potatoes, alfalfa, and roses and other field grown flowers (Anonymous 1971a, 1972a). Similarly, the soybean looper infested bush beans, bell peppers, cole

crops, cotton, potatoes, celery, and field grown flowers (Anonymous 1971a, 1972a), and substantial infestations of the tobacco budworm were reported to have occurred in soybeans and pigeon peas (Anonymous 1971a, 1972a). Obviously infestations of the cabbage looper, soybean looper, and tobacco budworm occur quite frequently on host plants other than their most well-known hosts and these so-called "alternate hosts" probably have a great influence on the population dynamics of the different species. Therefore, an increased knowledge of host preferences of these species should help in understanding and anticipating infestations on various hosts, and help in developing management schemes to prevent or limit infestations on some selected hosts.

Therefore, the purpose of the studies reported in this section were (1) to determine seasonal abundances of cabbage looper, soybean looper, and tobacco budworm, and evaluate density prediction capabilities as measured with various sampling techniques (in an 8-acre cropping system in northern Florida); and (2) to determine the relative abundance and host plant preferences of these pests with a special emphasis on domestic crops grown in northern Florida.

Literature Review

Seasonal Occurrence and Abundance

Cabbage looper

The cabbage looper has been reported on 119 host plants (Sutherland 1965). It has been collected from some host plants growing in the wild including wild crucifers and wild tobacco, Nicotiana glauca (McKinney 1944), lambsquarters, Chenopodium spp. (Crumb 1956), and ground ivy, Glechoma hederacea, wild radish, Raphanus raphanistrum (Sutherland 1966),

and several other wild hosts (Sutherland 1965). In his studies, Sutherland (1966) could not find it on wild crucifers in New York in the spring; however, he may not have allowed adequate time for detectible numbers to increase on these hosts before he began sampling.

Sutherland (1966) found from laboratory, insectary, and field studies that the cabbage looper can successfully develop on a wide range of hosts including cabbage, collards, tomatoes, bush beans, peppers, squash, and turnips, but that development was slow on some hosts such as peppers. In a caged test, survival of cabbage looper was better on cabbage and tomatoes (71 and 70%) than potatoes, lima beans, lambsquarters, and peppers (57-32%). From laboratory studies, Shorey et al. (1962) found, however, that the cabbage looper can develop more rapidly on lima bean foliage than on cabbage foliage.

Despite the fact that the cabbage looper has been reported to develop on a number of host plants, cultivated and wild, it appears to favor cultivated crucifers over other hosts. Host preferences of the cabbage looper will be discussed more thoroughly in later sections dealing specifically with that subject.

From observations of cabbage looper immatures that occurred on some of its "favored" hosts in various parts of the U.S., varying numbers of generations per year have been reported (Sutherland 1965). For instance, McKinney (1944) believed 5-7 occurred per year in Arizona, Quaintance (1896) reported 6 for Florida, and Britton (1933) reported 2 occurred in Connecticut. Most recent reports indicate that the cabbage looper can occur mostly year-round in the southern areas of the U.S., but that it is limited to a short growing season in the north.

Cabbage loopers have either been absent or at low densities during

the winter in most studies on seasonal occurrences. It can overwinter in parts of South Carolina (Reid and Bare 1952), Louisiana (Smith and Brubaker 1938), Texas (Wolfenbarger 1967), Arizona (McKinney 1944), and California (Oatman 1966). Studies by Endris (1973) indicated that the cabbage looper could overwinter in northern Florida; in the winter of 1972-73, it overwintered and reproduced on St. George Island in northern Florida (Lingren personal communication).[1] However Mitchell (1973b) thought it likely that the cabbage looper reproduced and developed throughout the year only in southern Florida. In contrast it has even been proposed that cabbage loopers might overwinter in the extreme northern U.S. (Sirrine 1899; Dustan 1932; Huckett 1940). However, Sutherland (1966) in New York, Hofmaster (1961) in Virginia, and Elsey and Rabb (1970) in North Carolina found from their observations it did not overwinter in these areas. In view of the conflicting reports it is likely that the overwintering range of the cabbage looper varies with the severity of the winter.

The abundance of the cabbage looper on various hosts occurring in the winter and other seasons has been reported for a number of areas of the U.S. (Greene 1973). Densities reported varied greatly of course because of changes in regions, weather conditions, hosts sampled, cultural practices, sample size, and other factors; and Greene (1973) pointed out that host plant density as well as maturity and host preferences would affect the real area abundance or potential abundance for various cabbage looper (sub)populations reported.

Reports on seasonal abundance of the cabbage looper in south or mid-

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[1] P. D. Lingren, Cotton Insects Res. Laboratory, Agr. Res. Serv., USDA, College Station, TX.

Florida (Wilson 1957; Poe 1972; Strandberg personal communication[2]), south Texas (Wolfenbarger 1967), Arizona (McKinney 1944), and southern California (Oatman 1966; Oatman and Platner 1969, 1972) show that the cabbage looper can occur at high densities early in the spring and late in the fall. In these areas it is often at high densities on cabbage, lettuce, tomatoes, and some other crops during March-June and August-December. As far north as South Carolina, Reid and Bare (1952) found major peaks of cabbage looper in cabbage during September, November, and May.

Farther north Hofmaster (1961) found the highest numbers of cabbage loopers occurred on cabbage during August, but none could be found by late October. Similarly, Wieres and Chiang (1973) found in some Minnesota cabbage, highest densities of the cabbage looper occurred in August with very low densities by mid- to late September. In New York, Sutherland (1966) found few cabbage loopers after September, and the earliest date they were detected was June 14. Even farther north in eastern Ontario, Harcourt et al. (1955) found that cabbage loopers did not occur until late in the cabbage-growing season, and even then were rarely found.

One of the earliest seasonal abundance studies dealing with the cabbage looper occurred in Louisiana in an area at a similar latitude as Quincy, FL (Smith and Brubaker 1938). Highest density of larvae found on cabbage sampled September to May was 11.98 per plant in early November.

Finally, some of the most extensive studies on seasonal abundance of immatures of the cabbage looper took place in southern California (Oatman 1966; Oatman and Platner 1969, 1972). In successive plantings of cabbage

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[2]Letter dated November 13, 1973 from J. O. Strandberg, Agr. Res. and Educ. Center, Univ. of Florida, Sanford, FL.

sampled from April, 1963 to April, 1965 (Oatman and Platner 1969), the greatest densities of eggs of cabbage looper (4.6 and 2.6 per plant) occurred in September and October of 1963 and 1964, respectively, and the lowest densities (0/plant) occurred in January. Major peaks in egg densities also occurred in May, August, and November. Also, larval numbers were highest in September and October (9.5 and 4.1 per plant), but other major larval peaks occurred in May, June, August, November, and December. Larval densities were lower from January through April than during other periods of the year.

In lettuce in southern California, Oatman and Platner (1972) found mostly low densities of the cabbage looper. Peak numbers of eggs and larvae occurring on lettuce for the growing season of November, 1966 to January, 1967 were 0.36 per plant and 0.28/plant, respectively. For the growing season from November, 1967 - January, 1968, peak egg and larval numbers were 0.82 and 0.60 per plant, respectively.

In his review, Greene (1973) suggested the need to relate seasonal abundances of immatures of the cabbage looper on cash crops, to adult cabbage looper capture data, in order that the relatively easy adult sampling techniques might be perfected somewhat, and utilized in predictive schemes. Falcon et al. (1967a, b) felt that blacklight (BL) trap information could be utilized for effectively predicting infestations of cabbage loopers in cotton and assessing population trends of the cabbage looper. Similarly, in studies ir northern Florida (Greene 1971) and central Florida (Strandberg personal communication) there seemed to be a positive correlation of BL trap captures of adult cabbage loopers with cabbage looper eggs in the field. Also, basic work on a mathematical model for describing cabbage looper behavior in relation tc light traps

has been reported by Hartstack et al. (1971). However to date trap catches of adult cabbage loopers has not been developed to the point where they can be utilized consistently for predicting immature numbers on crops.

Soybean looper

Soybeans and cotton have been two of the most commonly reported hosts of the soybean looper (Anonymous 1971a, 1972a), but few studies have been conducted on seasonal occurrence and abundance of soybean looper on any host. However, Burleigh (1972) did report that the soybean looper completed 4 generations per year on soybeans in Louisiana. Also, Endris (1973) found that it could survive the winter as far north as Gainesville, FL.

The only major study on seasonal abundances of immatures of the soybean looper was conducted by Burleigh (1972) on soybeans for 2 years in 3 different "agro-ecosystems." In this study, larvae were found from June through September, with maximum densities over 20,000 per acre occurring in September in a "cotton agro-ecosystem," the system which received the heaviest insecticide treatment. Lower densities were recorded in a "cleared hardwood agro-ecosystem" with lowest larval densities occurring in a "rice agro-ecosystem." High peaks of larval densities generally occurred in late August or early September in all systems, but in 1 year densities were highest in early July in the "rice agro-ecosystem."

In addition to Burleigh's report on seasonal abundances the soybean looper has been reported to occur in sweet corn in late May and June in south Florida (Janes and Greene 1970), in various crops, May-October in Alabama (with highest numbers in August and September) (Canerday and Arant 1966), in sunflowers in October near College Station, TX (Teetes et al. 1970), and at high densities in soybeans in Alabama (Harper and

Carner 1973) and South Carolina (Carner et al. 1974) during late August and September.

In the sunflower study, densities as high as 52,320 per acre were reported (Teetes et al. 1970). The sunflowers of Teetes et al. (1970) occurred in an area with high acreages of cotton, and Jensen et al. (1974) showed that nectar from cotton utilized by soybean looper adults might increase the potential for outbreaks of this pest.

Mitchell et al. (1975) reported on seasonal abundance of soybean loopers captured by synthetic sex pheromone - baited BL traps, but did not relate them to immature occurrence and abundance. They found no adult activity in a northern zones, where mean winter temperatures are often below 10°C, and that adult activity was significant in a southern zone (most of Florida) where mean winter temperatures exceeded 12.6°C. They concluded that the soybean looper survives the winter in Florida, increases there in the spring, moves northward into Georgia and South Carolina in the summer, and then migrates southward in late September and October.

Prediction of occurrence of the soybean looper in its preferred crops might be achieved by using adult capture data. However, the feasibility of such techniques has not been documented.

Tobacco budworm

Similar to the cabbage looper, the tobacco budworm has been found from a number of hosts (Chamberlin and Tenhet 1926b; Barber 1937; Brazzel et al. 1953; Snow and Brazzel 1965; Snow et al. 1966; Neunzig 1969; Teitz 1972; Lincoln 1972); however, wild hosts appear to be more important in the development of tobacco budworm populations than in the development of cabbage looper populations. Tobacco and cotton appear to be the favored cultivated host, with tobacco apparently usually favored over

cotton when both are available (Lincoln 1972). Host preferences will be covered in more detail in later sections.

Although tobacco budworm probably migrates over considerable distances, and it does normally go into diapause in the pupal stage in the fall in order to overwinter, it appears to be limited to a southerly range. This may be largely due to a southerly range of its favored hosts. However, there is, of course, considerable variations in seasonal occurrence and abundance of the tobacco budworm within its range in the U.S.

Neunzig (1969) found that the tobacco budworm emerged from diapause in North Carolina during a period from late April through early May. Lincoln (1972) concluded "eggs are first found in April in central Texas, central Mississippi, and southern Arkansas. Thereafter, larvae are continuously present through October." In extreme south Texas, the tobacco budworm is active throughout the winter (Fife and Graham 1966; Graham and Robertson 1970) and probably goes through several generations per year.

Chamberlin and Tenhet (1926b) found that 5 generations occurred per year in northern Florida, but that the tobacco budworm was not active after October. Further north, Neunzig (1969) concluded that it was capable of completing only 4 generations per year in North Carolina.

Since its range in the U.S. appears to be more limited than the cabbage looper, season occurrence and abundance of the tobacco budworm seem to be more dependent on available favorable host plants than on favorable climatic conditions. Lincoln's (1972) discussion of the problem of determining the seasonal abundance of the tobacco budworm is also applicable to the cabbage looper and the soybean looper. He said that although the tobacco budworm is strongly influenced by the availability in sequence of favorable hosts, "populations are difficult to quantify.

Infestations are found on many different species of plants, including uncultivated ones. Sampling the assorted hosts to obtain comparable data is hardly possible. Estimating acreage of a weed in mixed and scattered stands cannot be done accurately. Some hosts may be heavily infested, but contribute little to population buildup because of parasitism, predation, or nutritional inadequacy of the host."

Major hosts for the 1st (spring-early summer) generations of the tobacco budworm include wild hosts such as crimson clover (Brazzel et al. 1953; Snow and Brazzel 1965); wild tobacco, Nicotiana repanda; Verbena neomexicana (Graham et al. 1972); toadflax (Barber 1937; Neunzig 1963, 1969); and Carolina cranesbill, Geranium carolinianum (Snow et al. 1966); and cultivated hosts such as tobacco (Chamberlin and Tehnet 1926a; Neunzig 1969) and tomatoes (Graham et al. 1972). Minor hosts have included white clover, vetch (Lincoln 1972), Verbena bipinnatifida, Solanum eleagnifolium, Gaura parviflora, Malvaviscus drummondii (Graham et al. 1972), and persian clover (Snow and Brazzel 1965).

For mid-season (summer) generations the cultivated hosts, tobacco (Brazzel et al. 1953; Snow and Brazzel 1965; Neunzig 1969) and/or cotton (Brazzel et al. 1953; Snow and Brazzel 1965; Neunzig 1969; Graham et al. 1972) serve as major hosts of the tobacco budworm although okra, tomatoes, and alfalfa (Lincoln 1972) may also be important. Wild hosts, including hop clover (Snow and Brazzel 1965), toadflax (Neunzig 1969), deergrass, Rhexia spp. (Barber 1937; Neunzig 1963, 1969), and Ruellia runyonii, Rumex sp, Passiflora foetida, Schrankia latidens and Ratibida columnaris (Graham et al. 1972), generally had very low densities of tobacco budworm during mid-season.

For the late season (late summer-fall) generations of tobacco budworms, a complex of wild hosts appear to be very important. Beggarweed,

Desmodium spp. (Barber 1937; Snow and Brazzel 1965); deergrass (Neunzig 1969); and R. runyonii (Graham et al. 1972) appear to be major hosts in some areas, but tobacco budworms are also found on small flower morning-glory (Brazzel et al. 1965); spider-flower, Cleome spinosa; Haplopappus divaricatus (Snow and Brazzel 1965); Abutilon trisulcatum; P. foetida; Dalea pogonathera (Graham et al. 1972); and morningglory, Ipomaea trichocarpa (Lincoln 1972). However, development of later generations on cultivated hosts such as okra (Snow and Brazzel 1965), tomatoes, squash (Graham et al. 1972), late or 2nd-growth cotton, soybeans, and alfalfa (Lincoln 1972) may be just as important as development on the wild host complex, or more so.

As was pointed out by Lincoln (1972), it is very difficult to relate seasonal abundances reported from one area to another and from one host to another. Graham et al. (1972) did attempt to determine the area covered by many of the hosts of tobacco budworms in their study area in south Texas and attempted to determine densities of tobacco budworms occurring in the various hosts. They reported highest densities of tobacco budworm larvae occurred in wild tobacco (at a peak of 0.45 per plant) and tomatoes (at a peak of 0.22/row-ft) during the spring (early and late May). After early June and during the summer larvae were commonly found at densities greater than 0.2 per row-ft in insecticide-treated cotton. Densities were similar in tomatoes and squash during the fall.

During the spring in northeast Mississippi, another cotton-producing area, highest densities of the tobacco budworm were found in crimson clover and Persian clover (Snow and Brazzel 1965). Densities peaked at 16 larvae per 100 sweeps in crimson clover and 40 larvae/100 sweeps in Persian clover in early May.

During the spring and summer in North Carolina tobacco, numbers of tobacco budworm larvae fluctuated from ca. 0.30 per plant to 1.00/plant (Neunzig 1969). Major peaks in densities occurred during most months from May through September with maximum numbers found in August.

In the early part of this century Chamberlin and Tenhet (1926b) conducted studies on the seasonal abundance of the tobacco budworm near Quincy, FL, close to where the study presented herein was undertaken. In cage studies they found tobacco budworms emerging in the spring from April 28 to June 11. However, in some seasons they found tobacco budworm eggs in tobacco seed beds during March. They felt there were 5 generations of the tobacco budworm in northern Florida, with the 1st and 2nd generations developing on tobacco, the 3rd on tobacco and beggarweed, and the 4th and 5th during September and October on beggarweed. Chamberlin and Tenhet (1926b) reported that although tobacco budworms were pests of okra on the Virgin Islands, they were rarely found on okra growing near Quincy. Also only a few were found on tomatoes.

An extensive research effort to relate seasonal abundances of immature Heliothis spp. and adult trap capture data has been made by Hartstack et al. (1973) in a Texas cotton-producing region. In their attempt to survey the population dynamics of the tobacco budworm, they reviewed pertinent literature on this subject and found that only a limited amount of work had been done that was useful in estimating and predicting infestations of tobacco budworms on various crops with adult trap information.

Since the review of Hartstack et al. (1973), however, Hendricks et al. (1973) found that saucer-type pheromone traps detected low levels of the tobacco budworm better than BL traps. And in more extensive studies in South Carolina, Roach et al. (1975) verified this. Both Roach et al.

(1975) and Hendricks et al. (1973) found that BL trap catches are generally inversely proportional to pheromone trap catches. This indicates that at high densities, pheromone traps may not be effective because of competition from native females.

Hartstack et al. (1973) found that probably 70% of the tobacco budworms in the Brazos bottom near College Station, TX, emerged from March 10 to April 30, and that the mean rate of increase (actually the population trend index (I)) calculated from accumulated BL trap catches was 1.40 from April 30 to July 9, and 5.75 from July 9 to September 17. They found "rates of increase" were reduced by as much as 80% on nights of the full moon during June, July, and August. Tobacco budworm captures were very low in April and May, but increased rapidly from June, and peaked in September (Hartstack et al. 1973). Catches decreased in October and none were caught in November. Most tobacco budworms were caught in traps placed near cotton.

The data collected by Hartstack et al. relating to estimation of numbers of adults of Heliothis spp. generation development time, rates of increase, and host affinity was used to develop a predictive model for Heliothis spp. This model has "provided encouraging results when used for predicting when and how large the next generation of Heliothis spp. adults might be." However, the model of Hartstack et al. (1973) was primarily for corn earworm, Heliothis zea (Boddie) rather than tobacco budworm. A great deal more knowledge about the tobacco budworm needs to be acquired before a reliable predictive model can be developed for this species.

Host Preference

Cabbage looper

As has been discussed previously, it is generally believed that domestic crucifers are preferred hosts of the cabbage looper but a wide range of host plants (at least 119), including several wild hosts, have been reported for the species (Sutherland 1965). Even though many host plants for the cabbage looper have been identified, little information is available that establishes host plant preferences of the species. However, host preference studies by Elsey and Rabb (1967) indicated that the cabbage looper preferred collards over tobacco as sites for oviposition. In other host preference studies in field cages, cabbage loopers preferred cotton and collards as oviposition sites when these crops were compared with broccoli, cauliflower, or cabbage (Boling and Pitre 1971).

Other information on host preference of the cabbage looper can be gleaned from various investigations of host plant resistance of some crucifers to cabbage looper infestations. In these studies some species of crucifers seemed to be preferred over others for oviposition sites (e.g. collards, broccoli, and cabbage). However, results were usually confounded by the variability of the physical condition of the plants used (Harrison and Brubaker 1943; Radcliffe and Chapman 1966; Sutherland 1966).

Soybean looper

Soybeans have been reported as the primary host for the soybean looper in Louisiana (Hensley *et al.* 1964) and Alabama (Canerday and Arant 1966). But in these and other areas, major infestations have been reported on other crops. The soybean looper has been reported as a pest of peanuts in Alabama (Canerday and Arant 1966), sweet potatoes and cotton

in Alabama and Louisiana (Hensley et al. 1964; Canerday and Arant 1966), sweet corn in southern Florida (Janes and Greene 1970), and floricultural crops in southern California (Morshito et al. 1967). Tomatoes (Canerday and Arant 1966), tobacco, collards, beans, lettuce, alfalfa, wandering-Jew, Commelina spp.; Croton capitatus (Crumb 1956); goldenrod, Solidago sp.; Geranium sp. (Eichlin and Cunningham 1969); and guar (Teetes et al. 1970) have also been reported as soybean looper hosts. Furthermore, Fuchs et al. (1973) found that 11% of the Plusiinae in some of their cabbage plots were soybean loopers. However, although these and other hosts have been reported for soybean looper, no specific studies have been reported on host preferences.

Tobacco budworm

Tobacco and cotton are major host plants of tobacco budworm, but it also attacks tomatoes, soybeans, and many other crops and wild hosts (Lincoln 1972). Teitz (1972) listed 31 hosts that have been reported for tobacco budworm. Many studies in various regions of the U.S. have been conducted on the host plants of tobacco budworm and of the seasonal occurrences of Heliothis spp. on them. Most were reviewed by Snow and Brazzel (1965), Neunzig (1969), and Lincoln (1972). These studies indicate tobacco is the preferred host of the tobacco budworm.

Still, no specific studies of tobacco budworm preferences among various crops have been reported. Greene and Thurston (1971) did point out the preference of the tobacco budworm for certain species of tobacco, particularly those with pubescent leaves and showing many protruding trichomes. Another investigation, by Lukefahr and Shaver (1972), has demonstrated differences in oviposition rates of the tobacco budworm on

certain lines of cotton. Plant characteristics such as the presence or absence of extrafloral nectaries and pubescence, influenced preference for or against a certain line.

Methods and Materials

Seasonal Occurrence and Abundance

Data on immatures of Plusiinae and Heliothis spp. were taken during all seasons in all crops in the 8-acre cropping system, and during some seasons in some other areas near the system, from December, 1971 to September, 1973. The techniques are described in Section I.

In addition, adult numbers were monitored with light and pheromone traps. A baffled 15-w fluorescent blacklight (BL) trap (ca. 10-15 ft above the ground) similar to that described by Harding et al. (1966), was operated on the northeast and southwest ends of the 8-acre system, ca. 130-260 ft from the edges of the system (Fig. 1). BL traps were baited monthly with 0.04 dr (0.15 ml) synthetic cabbage looper sex pheromone, cis-7-dodecen-1-ol-acetate (cis-7-dda), dispensed from a 0.4 dr polyethylene vial placed on the BL trap post, ca. 4 ft from the ground.

Cylindrical electric-grid traps (Kishaba et al. 1970; Mitchell et al. 1972) were placed at the north, east, south, and west corners of the system (ca. 130-260 ft away). Opposite grid traps (e.g. N and S or E and W) were generally baited with five (infrequently 10 to twenty) 2-to-3-day-old virgin female cabbage loopers or tobacco budworms. Grid traps were baited once a week (December 5, 1971-May 14, 1973), or at 3-4 day intervals (May 14, 1973-August 16, 1973).

Moths attracted to and capture by the traps were funneled into a 6 x 12 in. cylindrical vinyl basket containing a dichlorvos-impregnated

polyvinyl chloride strip. Moths were collected 2-7 times a week during the study and brought into the laboratory and identified (Brazzel et al. 1953; Habeck 1968). Species of Plusiinae and Heliothis were counted and sexed. The degree of mating of female cabbage loopers, soybean loopers, and tobacco budworms was monitored by dissecting the bursa copulatrix (Callahan 1958), and counting numbers of spermatophores.

Moon phases were obtained from U.S. almanacs for 1971, 1972, and 1973. Therefore, they are not indicative of true moonlight intensity since cloud cover and other environmental factors affecting the moonlight were not recorded. Also, there was a house (light source) near both BL traps and a security light near the north grid trap.

Host preferences

In an initial experiment on host preferences, I released 90, 522, and 200 pairs of 1 to 3-day-old moths of cabbage looper, tobacco budworm, and soybean looper, respectively, in the 1-acre cigar-wrapper tobacco shade (Fig. 2) during the period from August 15 to September 8 (Table 1). Larger numbers of tobacco budworms and soybean loopers were released because of difficulty in establishing populations of these pests in the 1-acre shade. Moths were taken to the shade just prior to sundown in 1-gal containers and released onto the crops while walking diagonally across crops of the 1-acre shade.

After moth releases, populations of immatures of the test species were sampled (Section I) on 19 dates from August 16 to September 22. Estimates of larval densities were used to establish crop preferences. Data on number of larvae of each test species found per 10 row-ft over the 7 crops on all the sampling dates underwent an analysis of variance.

Differences in means were separated using Duncan's multiple range test at the 1% level of probability.

In a 2nd experiment the oviposition preferences of the tobacco budworm, soybean looper, and cabbage looper were determined for crops tested in the 1st experiment, plus cocklebur. In this test, 2 plants of each crop and cocklebur were transplated at random in a 6 x 4 x 5 ft cage enclosed with screen wire; then adults of the test insects were added. The plants were allowed to stabilize for 1 week before moth releases were begun.

Cocklebur was added to the test because it is very common in the Quincy area and Lingren (personal communication) had observed larvae of some species of Plusiinae feeding on this plant in cigar-wrapper tobacco shades. However, Kincaid (1960) had suggested cockleburs were a good cover crop to grow in rotation with cigar-wrapper tobacco and the weed has been allowed to grow in tobacco shades in the area.

In the small cage, tomatoes and cockleburs appeared to be in the best condition with tomatoes possessing about twice as much foliage as other host plants. Host plants other than tomatoes and cocklebur were in about "equal" condition.

Moths were released into the small cage and egg counts taken as follows: cabbage looper, 15 pair of 2- to 4-day-old moths released on September 22 with egg counts taken 1, 3, and 6 days after release; soybean looper, 10 pair of 1- to 4-day-old moths released on September 9 and 15, and 20 pair released on October 6, with egg counts taken 1, 2, 3, and 5 days after the 1st release, 1, 2, 3, and 6 days after the 2nd release, and at 2 days after the 3rd release; tobacco budworm, 30 and 15 pair of 3- to 5-day-old moths released on August 30 and September 9, respectively, with egg counts taken at 2 and 4 days after the 1st release

and 1, 3, 4, 6 and 9 days after the 2nd release. Adults of the soybean looper and cabbage looper were added at different times so that their eggs could be properly separated. Data on number of eggs of each test species found per plant over the 8 hosts on all of the sampling dates were analyzed as described for the 1-acre shade.

For the set of data presented for each test species from the 8-acre cropping system, seasonal means of number of Plusiinae and Heliothis spp. per acre were obtained from weekly estimates as described in Section I. These weekly estimates were combined and seasonal means for the included species obtained by applying percentile values corresponding to the species composition as estimated for each season based on identified samples. Seasonal means for the particular species were then averaged to obtain the "means" reported herein.

Results and Discussion

Seasonal Occurrence and Abundance

Cabbage looper

The only crops in the 8-acre cropping system from which we identified cabbage loopers were collards, cabbage, soybeans, flue-cured tobacco, tomatoes, okra, and white clover (Table 2). Results indicated cabbage looper larvae were found only during 8 of 49 weeks of sampling in crops other than collards and cabbage and densities were almost too low to be detected by the sampling procedure employed. (They were generally estimated at less than ca. 700 per acre.)

Cabbage loopers were found in soybeans, tomatoes, flue-cured tobacco, white clover, and okra in the spring. No cabbage loopers were found from samples of wild hosts in any season.

Numbers of cabbage looper eggs and larvae estimated per acre in collards and cabbage from March through May in 1972 and March through June

Table 2.--Relative occurrence of species of Plusiinae collected in crops in an 8-acre cropping system.

Crop	Number identified[a]	% of each species on indicated crop					
		Cabbage looper	Soybean looper	Autographa biloba	Argyrogramma verucca	Rachiplusia ou	Trichoplusia oxygramma
1972							
Collards	594	99.5	0.5	0.0	0.0	0.0	0.0
Cabbage	264	100.0	0.0	0.0	0.0	0.0	0.0
Soybeans	48	16.7	83.3	0.0	0.0	0.0	0.0
Tomatoes	7	0.0	100.0	0.0	0.0	0.0	0.0
Peanuts	1	0.0	100.0	0.0	0.0	0.0	0.0
Field peas	14	0.0	0.0	0.0	92.9	0.0	7.1
1973							
Collards	396	99.5	0.0	0.0	0.0	0.5	0.0
Cabbage	217	100.0	0.0	0.0	0.0	0.0	0.0
Tomatoes	6	100.0	0.0	0.0	0.0	0.0	0.0
Flue-cured tobacco	4	100.0	0.0	0.0	0.0	0.0	0.0
White clover	25	4.0	0.0	8.0	0.0	88.0	0.0
Okra	2	50.0	0.0	0.0	50.0	0.0	0.0
Soybeans	33	0.0	93.3	0.0	6.7	0.0	0.0
Bell peppers	2	0.0	50.0	0.0	50.0	0.0	0.0
Field peas	3	0.0	0.0	0.0	100.0	0.0	0.0
Peanuts	2	0.0	0.0	0.0	100.0	0.0	0.0

[a]Larvae were reared to adult stage and identified.

in 1973, periods when cabbage was present in the system, are presented in Table 3.[3] Most cabbage loopers in the system were found on these 2 crops. Estimates of eggs per acre in collards were significantly higher than those in cabbage, but estimates of larvae/acre were similar. Since collards were the most utilized host of cabbage looper in the 8-acre cropping system in all seasons, the reported seasonal abundance of immatures of this pest deals primarily with this crop.

Cabbage loopers were found in collards or adult traps of the system during most months of the period studied (Fig. 3a). Few eggs, larvae, or adults were found in the winter months and highest densities were found during September, 1972 and June, 1973.

In 1972 there were at least 7 major peaks of eggs (over 1000 per acre) in collards and eggs were estimated at over 10,000/acre during the weeks of April 23, May 7-28, June 11, June 25, July 2, 9, and August 20-September 17 (Fig. 4a). A peak egg density of ca. 41,170 per acre occurred during the week of August 27. In 1973 (January-July 25) all 5 peaks of eggs in collards were estimated at over 1000 per acre and eggs were estimated at 10,000/acre for the weeks of May 13-June 17 and July 8 (Fig. 4a). The highest egg density in 1973, amounting to 43,090 per acre, occurred during the week of June 10.

Four peaks of large larvae at densities greater than 1000 per acre occurred in 1972 and only 2 peaks above 1000/acre occurred in 1973 when sampling was terminated in August. The highest densities were 2670 and 1880 per acre in 1972 and 1973, respectively (Fig. 4a). Densities of small larvae (Fig. 4a) and medium larvae were generally intermediate to densities of eggs and large larvae.

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[3] Eggs of Plusiinae or Heliothis spp. were not identified to species but are generally labeled as being the major species identified in the larval stage from a particular crop, as described in Section 1.

Table 3.--Relative number of immatures of cabbage looper in collards and cabbage in an 8-acre cropping system during the spring of 1972 and 1973.

Date (Week of)	Ca. no./acre			
	Collards		Cabbage	
	Eggs	Larvae	Eggs	Larvae
		1972		
Mar. 5	0	0	-	-
12	0	0	0	0
19	0	-	0	0
26	60	560	0	0
Apr. 2	630	620	0	240
9	130	250	0	0
16	0	2,580	1,080	830
23	11,160	2,620	1,670	1,000
30	2,500	160	5,340	1,840
May 7	13,420	3,830	4,010	4,560
14	22,160	7,370	9,830	6,920
21	14,830	6,830	7,500	6,670
28	10,500	5,000	-	-
$\bar{x}$[a]	6,490	2,980	2,940	2,206
		1973		
Mar. 18	410	410	-	-
25	1,040	0	0	0
Apr. 1	0	0	0	0
8	2,910	0	500	170
15	4,790	2,090	8,830	1,330
22	2,090	6,250	0	3,670
29	2,190	3,960	1,600	2,000
May 6	3,960	8,340	5,170	2,330
13	14,750	5,880	18,170	15,830
20	13,600	4,790	10,670	18,500
27	14,160	15,000	16,170	15,000
Jun. 3	24,590	7,910	-	-
10	42,090	6,250	9,500	4,830
17	22,290	17,500	-	-
$\bar{x}$[b]	9,230	4,780	6,419	5,790

[a]Data from March 5, 19, and May 28 were not used to obtain means.

[b]Data from March 18 and June 3 were not used to obtain means.

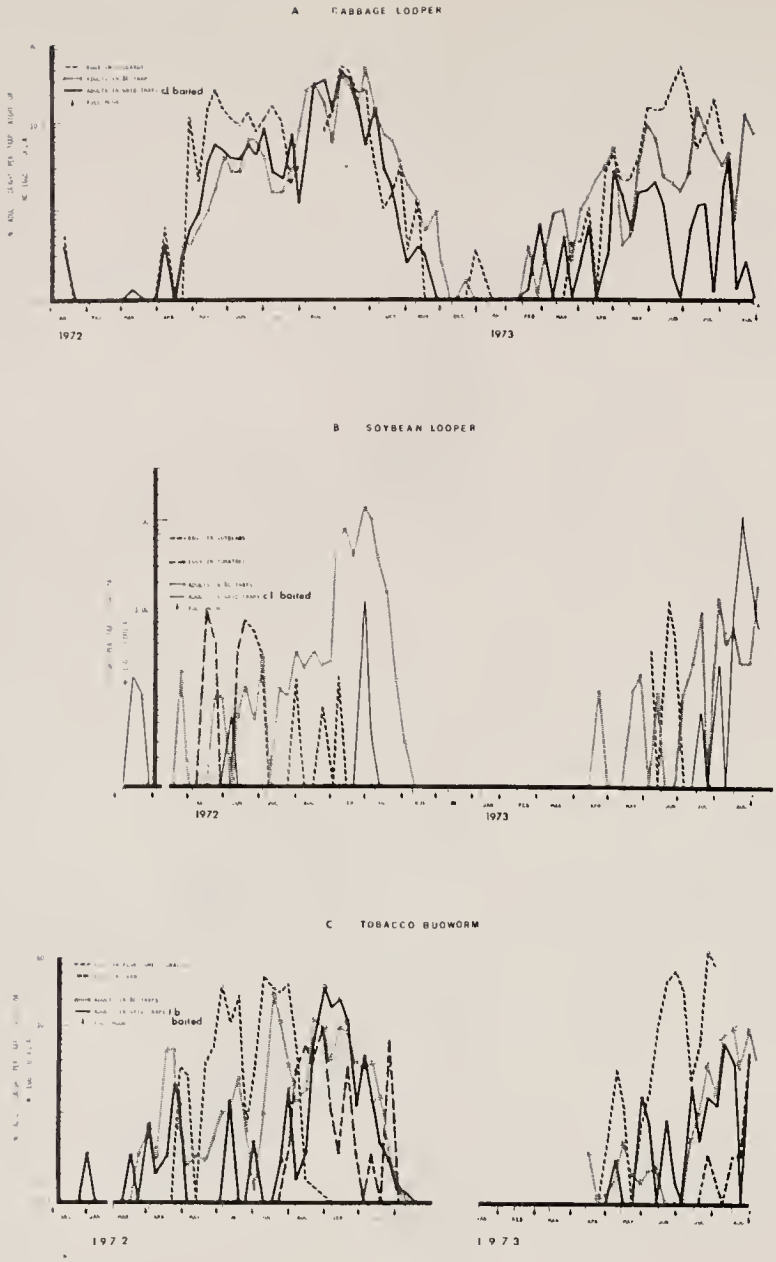

Fig. 3.--Mean number of cabbage looper, soybean looper, and tobacco budworm adults (mostly males) caught per blacklight trap baited with synthetic cabbage looper pheromone, or electric grid trap baited with virgin female cabbage looper or tobacco budworm /night compared with mean number of eggs of Plusiinae or Heliothis spp. in preferred crops in an 8-acre cropping system. Numbers of eggs found are plotted at the middles of weekly periods; points for adult numbers correspond to means of those adults caught during the week prior to the last egg sampling date during a week. Note that soybean looper are plotted on a different scale.

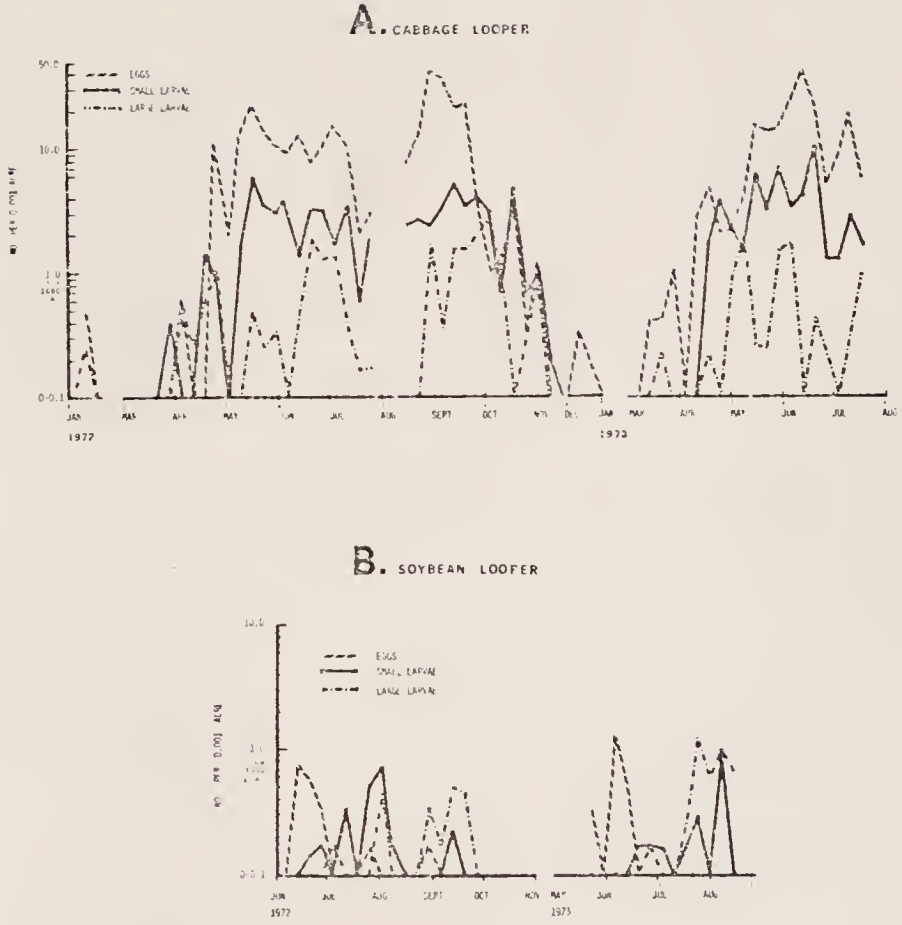

Fig. 4.--Seasonal abundance of eggs and larvae of cabbage looper in collards, and soybean looper in soybeans, in an 8-acre cropping system.

During the periods when no collards or cabbage were present in the cropping system (July 30-August 13, 1972 and July 22-August 19, 1973), few if any cabbage looper eggs or larvae were found in the system. During these periods, the only Plusiinae larvae present were collected from bell peppers. Though not identified with certainty, they were probably cabbage loopers.

Data on immatures (Fig. 4a) and adults (Fig. 3a) indicated there were 7-8 generations of cabbage looper in 1972 and 5-6 generations from January 1973-August 14, 1973. This is similar to what McKinney (1944) thought occurred in Arizona.

Cabbage looper adult catches with blacklight (BL) traps baited with cis-7-dda, and number of cabbage looper eggs in the field seemed to be positively correlated in 1972 but not in 1973 (Fig. 3a). However, increased rainfall in 1973 over that of 1972 may have influenced catches and accurate identification of the Lepidoptera trapped.

Also, capture of adults of cabbage looper in cis-7-dda-baited BL traps and virgin female-baited grid traps were very similar in 1972 but in 1973 they differed greatly (Fig. 3a). After early May of 1973, captures of cabbage loopers in grid traps were much lower than those of the BL traps, and during several weeks "peak" captures in the BL trap plot were "valleys" in the grid trap plot data (Fig. 3a). This may have been the inverse relationship Hendricks et al. (1973) and Roach (1975) reported for tobacco budworm and corn earworm.

The BL trap, grid trap, and egg count data (Fig. 3a) for cabbage loopers did not suggest that cabbage looper activity was strongly influenced by lunar phases as was demonstrated for tobacco budworm by Hartstack et al. (1973). However, lunar phase charts do not accurately

measure actual moonlight because of cloud cover and Lingren (personal communication) has accumulated data which indicates cabbage looper activity is strongly affected by moonlight intensity.

Hartstack et al. (1973) suggested that one parameter that might be estimated from BL trap captures is the "mean rate of increase" such as is illustrated in Fig. 5a. This view of the data is useful in illustrating potential predictive patterns. In the period from April 14-May 24 both BL trap capture data and eggs in the field were accumulating rapidly. Lower "rates of increase" and rapid decline in numbers of eggs in the period after September 26 are illustrative of the effect cool weather may have on the population density of the cabbage looper in this region. Accumulated BL trap captures of cabbage looper adults seemed to follow a similar trend in 1972 as 1973.

Relatively few cabbage looper females were captured in BL traps. Therefore data on mating was rather limited. However, the percentage of mated females caught was highest in May (Table 4) when populations of the cabbage looper were relatively low. Numbers of matings per female were greater during this period when pheromone calling by native females was probably most efficient. After May, percent mated females fluctuated from 41.4 to 61.1 except during those months when <5 females were caught.

The major findings concerning seasonal abundances of the cabbage looper was that it was very abundant in collards from May-September and was at very low densities in the winter. Also adult trap data may be a useful tool to employ in predicting seasonal occurrence and abundance of cabbage looper populations.

Soybean looper

The soybean looper was not as abundant in the 8-acre cropping system

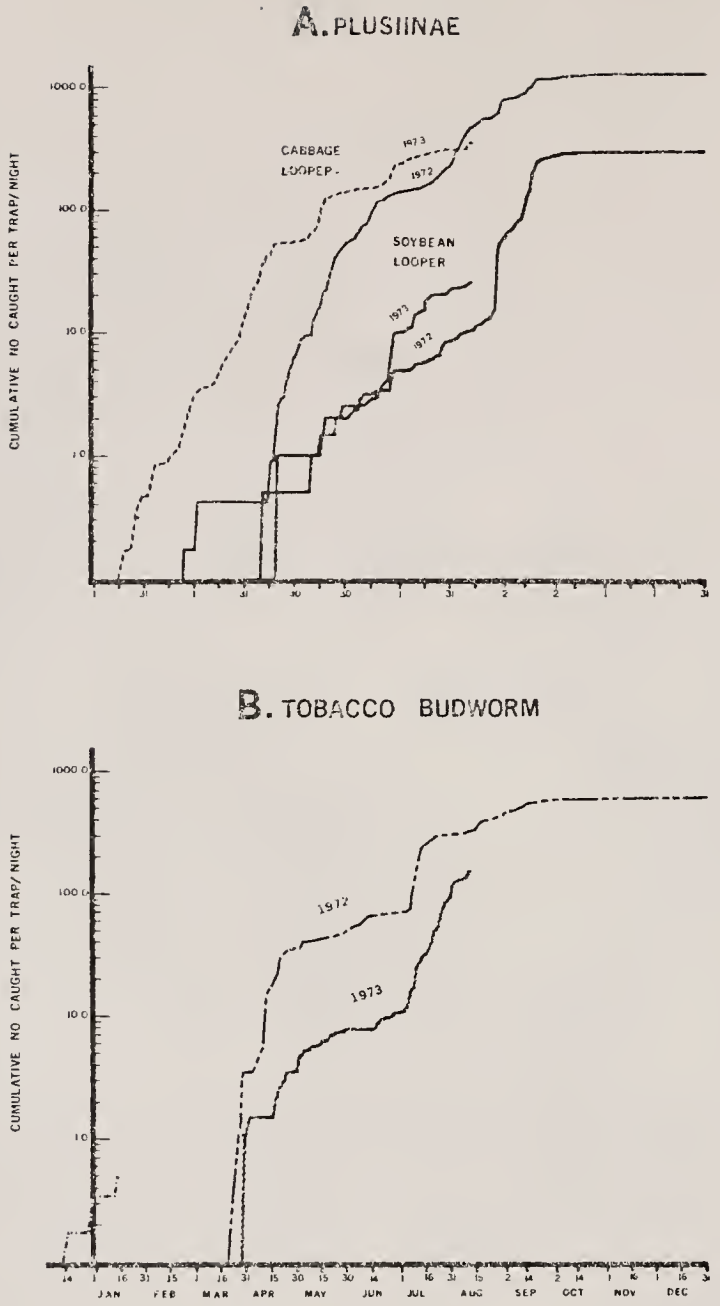

Fig. 5.--Rates of increase of cabbage looper, soybean looper, and tobacco budworm indicated by cabbage looper pheromone-baited blacklight trap captures of adults.

Table 4.--Degree of mating of cabbage looper, soybean looper, and tobacco budworm females trapped in cabbage looper pheromone-baited light traps surrounding an 8-acre cropping system.

Month	No. dissected	% mated ♀♀	Spermatophores/ ♀	Spermatophores/ mated ♀
		Cabbage looper		
1972				
April	1	0.0	0.0	-
May	10	90.0	1.1	1.2
June	10	60.0	1.7	2.8
July	15	46.7	1.0	2.0
August	87	41.4	0.8	1.8
September	12	41.6	0.5	1.2
October	4	0.0	0.0	-
1973				
May	17	64.7	1.7	2.6
June	18	61.1	1.6	2.5
July	22	59.1	1.2	2.0
August	4	0.0	0.0	-
		Soybean looper		
1972				
August	1	0.0	0.0	-
October	1	0.0	0.0	-
1973				
July	1	100.0	2.0	2.0
August	2	100.0	3.0	3.0
		Tobacco budworm		
1972				
March	10	100.0	2.3	2.3
April	60	95.0	4.5	4.8
May	17	76.5	1.1	1.5
June	25	88.0	1.9	2.2
July	265	81.9	1.6	1.9
August	22	86.4	2.2	2.5
September	43	69.8	1.4	2.0
October	5	20.0	0.2	1.0
1973				
May	2	100.0	2.0	2.0
June	2	100.0	2.5	2.5
July	25	84.0	1.6	1.9
August	26	46.2	0.6	1.3

as the cabbage looper, but was found in 5 of the 21 crops (Table 2). It was found most often in soybeans, however, tomatoes and peanuts also had relatively high densities of soybean looper in 1972 (Table 5). Tomatoes and peanuts were present in the system during much of the same period as soybeans (Fig. 1).

Only 3 soybean loopers were collected from crops other than soybeans, tomatoes, and peanuts in 1972 (Table 2). These occurred on collards early and late in the season (spring and fall) when soybeans were either absent from the system or not attractive as a host. All soybean loopers were found on soybeans in 1973 except 1 (Table 2). This collection was made in bell peppers during July, a period when soybean looper densities were relatively high on soybeans (Fig. 4b). No soybean loopers were collected and identified from the samples on wild hosts.

No immatures were found on plants within the 8-acre cropping system until late May or early June (Fig. 4b). Counts of immatures indicate the occurrence of only 3 generations in the system. However, densities were so low on the crops, it is possible a generation may have occurred that was not detected by the sampling techniques utilized.

In soybeans, densities of eggs and small (Fig. 4b) and medium larvae were estimated at or below 1000 per acre on every sampling date in 1972. In 1973 large larvae were estimated at densities of 1230 per acre during the week of July 20 and small larvae were estimated at 1000/acre during the week of August 5 (Fig. 4b).

Therefore the maximum densities of the soybean looper that occurred in my study area were much lower than those reported by Burleigh (1972) in soybeans growing in the "cotton agro-ecosystem" or by Teetes et al. (1970) in sunflowers. Low densities in the 8-acre system, which contrast

Table 5.--Relative number of larvae of soybean looper in soybeans, tomatoes, and peanuts in an 8-acre cropping system during the summer of 1972.

Date (Week of)	Ca. no./acre (whole plant inspections and shakes)		
	Soybean	Tomato[a]	Peanut[a]
Jun. 25	0	80	-
Jul. 2	0	0	0
9	1,000	0	0
16	0	0	0
23	500	0	0
30	920	1,000	1,330
Aug. 6	170	500	0[b]
13	80	-	0
20	80	-	80
27	330	-	-
Sep. 3	330	-	-
10	580	-	-
17	330	-	-
24	0	-	-

[a]Seven larvae from tomatoes, but only 1 from peanuts were identified from these crops. However, no other Plusiinae were identified from peanuts or tomatoes in 1972.

[b]Sweeps detected ca. 6.7 per 100 sweeps during this week.

with economic infestations that can be induced with insecticide-treatment of soybeans (Neal 1974), indicate that densities of the soybean looper throughout its seasonal development may "normally" be low in the absence of man's disruptive practices.

Although immature counts indicated 3 generations of soybean looper occurred in 1972 in the 8-acre system, BL traps seemed to detect at least 4 generations during that year (Fig. 3b), similar to what Burleigh (1972) found in Louisiana soybeans. Soybean loopers were first captured in cis-7-dda-baited BL traps in early April (Fig. 3b). They were caught until late October in 1972 and until sampling was terminated in mid-August in 1973. In 1972 there was a peak in catch of soybean loopers averaging over 10 per BL trap/night during September and October which was very high relative to numbers trapped earlier in the season. Most of these probably immigrated into the 8-acre system, and may have come from the nearby commercial soybeans mentioned in Section I. Or perhaps they were migrating from the norther part of their summer range (Mitchell et al. 1975).

Grid trap captures with cabbage looper-virgin female-bait were generally much lower and more inconsistent than captures in cis-7-dda-baited BL traps (Fig. 3b). This was perhaps because of substance(s) that may be emitted by cabbage looper females, which inhibit soybean looper attraction to female cabbage loopers (Mitchell 1972, 1973a).

Since adults of the soybean looper were caught prior to detection of soybean looper eggs or larvae in the field in the spring, it appears that BL traps may be helpful in warning of potential infestations of soybean looper. Also, as with the cabbage looper, there is no clear evidence from the data as developed and presented, of an effect of lunar phase on soybean loopers (Fig. 3b).

The semilog plot of accumulated catch of soybean loopers indicates "rates of increase" were quite constant during the period from May through August, but increased drastically in late August and September in 1972 and to a lesser degree in June of 1973 (Fig. 4a). The rapid increase may have been due to an influx of moths from commercial fields mentioned previously or a migration similar to what Mitchell et al. (1975) suggested might occur.

Only 5 soybean looper females collected from BL traps were checked for mating (Table 4). The 2 collected in 1972 had not mated and all 3 collected in 1973 had. Mean number of spermatophores in those which mated was 2.67.

The major differences between the seasonal occurrence and abundance of soybean looper and cabbage looper indicated from our data are that the soybean looper goes through fewer generations per year and it occurs at much lower density levels than the cabbage looper in the absence of applied control. It may have a lower intrinsic rate of increase as was suggested by Endris (1973) but "rate of increase" during some periods of my study (Fig. 5a) appeared to have been greater for the soybean looper than the cabbage looper. However, immigration of soybean loopers into my study area confound interpretation of the data. In contrast to data for the cabbage looper, adults of the soybean looper were taken in BL traps earlier in the spring than immatures were found in the field, in both 1972 and 1973.

Tobacco budworm

Tobacco budworms were found in 10 crops of the 8-acre cropping system, and in several wild hosts near the system (Table 6). They occurred in substantial numbers in flue-cured tobacco, cigar-wrapper

Table 6.--Relative occurrence of species of Heliothis collected in crops in an 8-acre cropping system.

Crop	Number identified[a]	% of each species on indicated crop	
		Tobacco budworm	Corn earworm
1972			
Flue-cured tobacco	433	99.8	0.2[b]
Cigar-wrapper tobacco	166	98.8	1.2[b]
Okra	178	79.2	20.8
White clover	42	64.3	35.7
Tomatoes	9	55.6	44.4
Peanuts	4	25.0	75.0
Grain sorghum	278	0.0	100.0
Sweet corn	253	0.0	100.0
Field corn	146	0.0	100.0
Millet	22	0.0	100.0
Soybeans	8	0.0	100.0
Cabbage	5	40.0	60.0
Bell peppers	2	0.0	100.0
Others[c]	5	0.0	100.0
1973			
Flue-cured tobacco	156	96.1	3.9
Collards	2	100.0	0.0
Okra	12	83.3	16.7
White clover	44	36.4	63.6
Soybeans	2	50.0	50.0
Tomatoes	4	25.0	75.0
Millet	5	20.0	80.0
Field corn	93	0.0	100.0
Sorghum	1	0.0	100.0

[a] "Larvae" were identified in some stage after the 3rd-instar.

[b] These larvae were identified in the adult stage to be corn earworm.

[c] Including 1 each from collards, field peas, bush beans, pumpkins, and squash.

tobacco, okra, and white clover, and infrequently (generally at densities <300 per acre) in tomatoes, collards, cabbage, millet and soybeans (Table 6). They were also found at very low density levels in peanuts. This contrasts with the studies of Snow and Brazzel (1953), in which no tobacco budworms were found from samples in peanuts. The wild host plants on which tobacco budworms were found included crimson clover, venus lookingglass, small flower morningglory, beggarweed, and prickly sida. Of all the wild hosts sampled, they were most numerous in crimson clover in the spring of 1973 and prickly sida in the summer of 1972.

Since crimson clover was quite abundant in the Quincy area in 1973 during the period in which tobacco budworm were emerging from diapause, it was probably a very important early season host of this noctuid this agrees with results of Brazzel et al. (1953) and Snow and Brazzel (1965). Tobacco budworms were also found on venus lookingglass in the spring, but plants of this species were very scarce.

Immature tobacco budworms were present in crops of the 8-acre system from early April to late October in 1972 and from early April in 1973 (Fig. 6). There were 6 major peaks in egg densities above 1000 per acre in the system in 1972 and 3 in 1973 (Fig. 3c).

Eggs of Heliothis spp. were first found from samples in or near the 8-acre system during April in flue-cured tobacco (Fig. 6b). Eggs were, however, undoubtly present in white clover at or before the time they were found in tobacco since large larvae were found in white clover during late April and early May in 1972 and 1973, respectively (Fig. 6a). Large larvae were also found on crimson clover at about this same time during 1973, and eggs were probably present on this host at about the time they were found in tobacco.

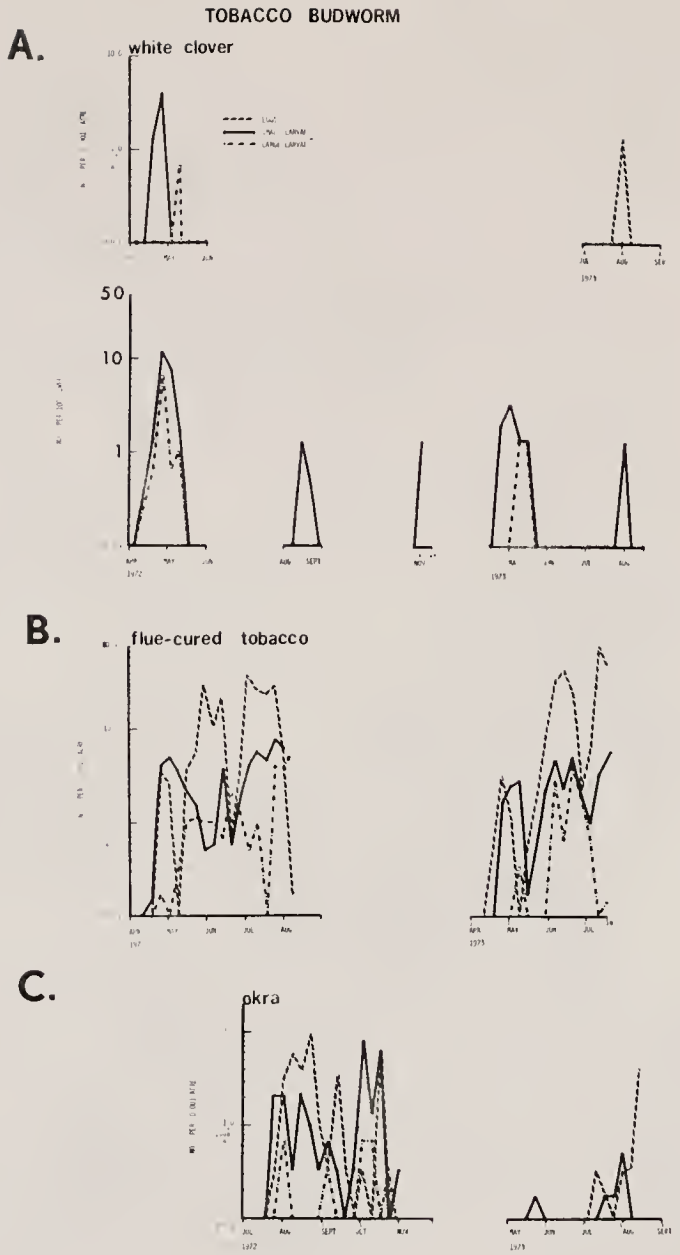

Fig. 6.--Seasonal abundance of eggs and larvae of tobacco budworm in flue-cured tobacco, okra, and white clover in an 8-acre cropping system, estimates include some corn earworm.

In white clover, which generally supported a portion of the tobacco budworm population only in the spring (Fig. 6a), large larvae occurred at a density of 680 per acre and 6.7/100 sweep during late April and early May of 1972. No large larvae were detected in whole plant inspections in 1973 and the maximum number found in sweeps in that year were down to 1.3/100 sweeps (Fig. 6a). An abundance of crimson clover during the spring of 1973 may have diluted densities of tobacco budworm in the white clover of the 8-acre system.

All tobacco budworms but 1 identified from tomatoes were collected in the spring, and the exception was collected on July 1, 1972. However, densities of larvae in this crop were very low and made an insignificant contribution to the population of the 8-acre system when compared to those occurring in white clover, tobacco, and crimson clover in the spring. In addition to crimson clover, venus lookingglass, white clover, tobacco, and tomatoes, a few tobacco budworms were also found in the spring in cabbage and collards in 1972 and 1973, respectively.

Tobacco in the 8-acre system was the major host of tobacco budworm; ca. 99% of the larvae of Heliothis spp. collected from flue-cured and cigar-wrapper tobacco were tobacco budworms (Table 6). And over 78% of the tobacco budworms collected and identified in the 8-acre system came from tobacco. Hence tobacco was the primary spring and summer host of tobacco budworm (Fig. 1 and 6). In flue-cured tobacco highest numbers of eggs occurred during the weeks of May 28 (29,830 per acre) and July 2 (37,170/acre) in 1972, and June 10 (43,670/acre) and July 8 (79,330/acre) in 1973 (Fig. 6b). The 1st peaks of small larvae occurring in the spring of 1972 and in 1973 were similar in size to egg peaks; however, subsequent peaks of small larvae occurring in the summer were considerably lower

Table 7.--Relative number of immatures of tobacco budworm in flue-cured and cigar-wrapper tobacco in an 8-acre cropping system in 1973.

Date (Week of)	Ca. no./acre			
	Flue-cured tobacco		Cigar-wrapper tobacco	
	Eggs	Larvae	Eggs	Larvae
Apr. 9	500	160	-	-
16	670	660	0	0
23	4,920	80	0	160
39	4,500	1,160	0	340
May 7	4,500	1,330	0	330
14	6,170	660	0	560
21	4,160	1,250	60	610
28	2,160	500	1,280	1,000
Jun. 4	2,160	1,080	1,940	940
11	6,160	330	3,560	1,660
18	12,500	0	60	3,610
25	4,830	80	1,660	2,000
Jul. 2	37,200	5,700	4,250	1,920
9	26,700	8,330	44,030	2,410
16	23,500	6,920	4,830	2,330
23	28,200	16,000	1,750	7,080
30	5,000	24,000	-	-
Aug. 6	170	6,170	-	-
$\bar{x}$[a]	11,220	2,940	4,228	1,660

[a]Data from April 9, July 30, and August 6 were not used for means.

than egg peaks. Estimates of large larvae per acre were considerably lower than estimates for eggs, with highest estimates occurring during the weeks of May 21 (1080), June 18 (2160) and August 6 (4920) in 1972 and June 3 (3000) and June 17 (4170) in 1973 (Fig. 6b).

The cheese cloth cage was apparently quite effective in preventing high levels of tobacco budworm infestations from occurring in cigar-wrapper tobacco. Weekly egg and larval estimates indicate densities of eggs in cigar-wrapper tobacco averaged 72% less than in flue-cured tobacco and levels of larvae averaged 43% less (Table 7). However, in late June the shade was ripped severely by winds and tobacco budworm eggs reached densities of 44,030 per acre.

Toadflax and hop clover had been previously reported as important early and mid-season hosts of the tobacco budworm (Barber 1937; Snow and Brazzel 1965; Neunzig 1963, 1969). However, they were probably not important in the Quincy area, since I found no tobacco budworms on these potential hosts after limited sampling of toadflax and extensive sampling of hop clover.

A number of tobacco budworms were found on prickly sida growing adjacent to the 8-acre system in the summer of 1972. However, densities of larvae were much lower than those that occurred in flue-cured tobacco. In addition to tobacco, prickly sida, and tomato, low densities of tobacco budworm larvae were also found on okra, peanuts, millet, and soybeans during early or mid-summer.

Similar to results of Snow and Brazzel (1965), but in contrast to the results in the Quincy area of Chamberlin and Tehnet (1926b), I found okra to be the major late season host in the 8-acre system. However, in okra, estimates of numbers of eggs and larvae per acre were considerably

lower than had been found in flue-cured tobacco (Fig. 6c). Highest peaks of eggs were estimated at over 1000 per acre during the weeks of August 20 (9500/acre), September 13 (3500/acre), and October 15 (6330/acre) in 1972 and August 12 in 1973 (4000/acre). Large larvae were never estimated at over 700 per acre. Most of the larvae collected in okra in October went into diapause.

In addition to okra, small flower morningglory (growing in or near the 8-acre cropping system) and beggarweed (growing in the Quincy area) were late season hosts of the tobacco budworm. Numerous eggs of Heliothis spp. were found on flowers of the small flower morningglory in the late summer and fall of 1972. Also, a substantial number of tobacco budworm larvae were collected from one stand of beggarweed growing some distance from the 8-acre system. Few plants of this host of tobacco budworm occurred near the system, however. A few tobacco budworm larvae were also collected in white clover in the fall of 1972.

Data on immatures (Fig. 6) and adults (Fig. 3c) indicated there were 6-7 generations of tobacco budworm in 1972 and 4-5 generations from January, through mid-August, 1973. Tobacco budworm adults were first found in cis-7-dda-baited BL or virgin female-baited grid traps in the spring on March 17 in 1972 and March 30 in 1973, and a few were captured during the warm winter of 1971-72 in both BL traps and grid traps (Fig. 3c). BL trap captures of tobacco budworm adults seem to be positively correlated with egg counts in tobacco and okra in 1972 but not in 1973 (Fig. 3c). This is similar to results for cabbage looper. Pheromone trap catches did not seem to be as effective as BL trap catches as indicators of the immature tobacco budworms in the field. The inverse relationship of captures data from pheromone and BL traps observed by

Hendricks et al. (1973) and Roach (1975) was not as apparent from our data; however, earliest captures of tobacco budworm in 1972, when the adults occurred at low densities, were made with pheromone traps.

BL and pheromone trap capture data on tobacco budworms (Fig. 3c) indicate tobacco budworm generation cycles may have been synchronized by lunar phase as hypothesized by Nemec (1971) for the corn earworm. However, egg counts did not reflect this trend.

The accumulated BL trap catches (Fig. 4) for tobacco budworm moths seemed to follow a pattern similar to that plotted by Hartstack et al. (1973). When "rates of increase" (from 1972) are calculated from points similar to those chosen by Hartstack et al. (1973), the trend is similar but reflects correspondingly higher population levels (2.29 and 8.33 as compared to 1.40 and 5.75). My higher "rates of increase" may indicate tobacco is a more favorable crop for tobacco budworms than cotton and/or that there was less mortality of developing tobacco budworms in the Quincy area. The higher catches per trap/night by Hartstack et al. (1973) in Texas are probably due to the more effective trap used (40-w BL vs. 15-w BL, see Hollingsworth and Hartstack 1972), less forested area in the Brazos Valley, and a greater abundance of suitable hosts in the vicinity of the traps. Our semilog plot of accumulated catch of tobacco budworms in 1973 seems to follow a trend similar to that of 1972; however, catches were lower (Fig. 4b).

Also similar to results of Hartstack et al. (1973), BL trap data indicated the corn earworm began emerging from diapause earlier than the tobacco budworm in the 8-acre cropping system (or Quincy area). This is similar to field cage studies of spring emergence of Heliothis spp. in northeast Mississippi (Brazzel et al. 1953), but different from similar

field studies in North Carolina (Neunzig 1969).

A substantial number of females of the tobacco budworm were collected in the BL traps near the 8-acre system (Table 4). Most were mated and mean number of spermatophores per mated females was estimated from 1.0/♀ in October to 4.8/♀ in April of 1972.

Results of measurements of the tobacco budworm population in the 8-acre cropping system were often comparable to those of the cabbage looper. For instance the tobacco budworm was able to reach high densities similar in magnitude to those of the cabbage looper. Also, the tobacco budworm went through a similar number of generations. These characteristics contrasted, however, with those of the soybean looper (Fig. 4 and 6).

Measurements of the population of tobacco budworms also differed greatly in several ways from similar measurements of the population of cabbage looper. Tobacco budworms were first detected in the spring by BL traps (Fig. 5), much later than cabbage loopers; however, the BL traps were baited with a synthesized pheromone of cabbage looper and soybean looper. Still, tobacco budworms were detected somewhat earlier in the spring than soybean loopers. Both tobacco budworms and soybean loopers appeared to "emerge" more suddenly in the spring than cabbage loopers (Fig. 5). Similar to a characteristic of the soybean looper detected with BL traps, there was a period during the summer months in which the tobacco budworm's "rate of increase" suddenly became greater. This growth in the "rate of increase" occurred earlier for the tobacco budworm than for the soybean looper, but also could have been due to immigration from fields outside the study area.

Host Preference

Cabbage looper

More cabbage looper eggs and larvae were present on collards and cabbage than other crops in all tests (Fig. 7a). In the 1-acre shade, 62 and 34% of larvae of the cabbage looper were found on collards and cabbage, respectively (Fig. 7a). In the small cage test, the portion of cabbage looper eggs found on collards (40%) and cabbage (30%) was singificantly greater than those found on other available host plants. Also, over 95% of the cabbage looper larvae found in the 8-acre cropping system were on collards and cabbage (Table 2).

In addition to collards and cabbage, a few cabbage looper larvae were found on bush beans, cigar-wrapper tobacco, and soybeans in the 1-acre shade (Fig. 7a), and on flue-cured tobacco, okra, soybeans, tomatoes, and white clover in the 8-acre system (Table 2). Also, cabbage looper eggs were found on all plants in the small cage with a substantial number on cocklebur.

These results indicate a strong preference of cabbage looper for collards and cabbage with crops such as tomatoes, tobacco, soybeans, okra, and white clover functioning as incidental hosts. Bell peppers and cigar-wrapper tobacco were infested under caged conditions, but not in the field. Therefore, it is likely that they are not normally a host of the cabbage looper. However, crop rotation systems in which any of these non-preferred hosts followed major plantings of collards or cabbage could create damaging infestations of the cabbage looper in the non-preferred hosts. Also, cocklebur should perhaps be controlled and not used in rotation with cigar-wrapper tobacco (Kincaid 1960), since substantial numbers of eggs were found on the plant in the small cage

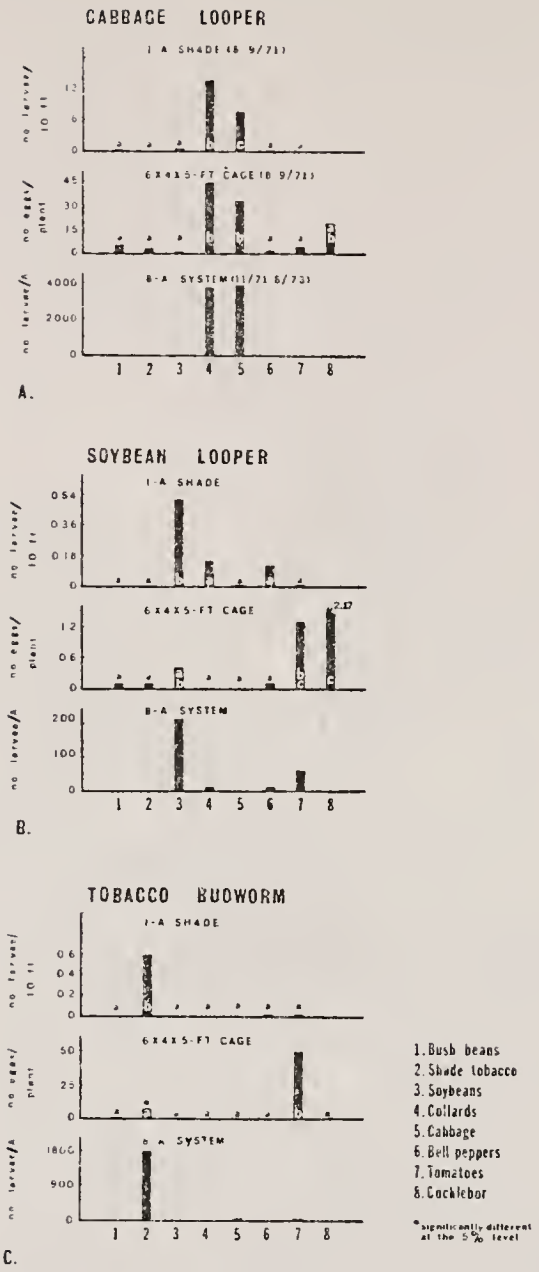

Fig. 7.--Mean number of eggs or larvae of cabbage looper, soybean looper, and tobacco budworm per sample date in 7 crops compared in a 1-acre shade, a 6 x 4 x 5-ft cage, and an 8-acre cropping system. Cocklebur were included in the small cage. Crops in the 8-acre system were seasonal with 14 additional hosts present during the sampling period; means for each cropping system with the same letter are not significantly different at the 1% level according to Duncan's new multiple range test.

test and since Lingren (personal communication) has previously observed larvae of Plusiinae feeding on cocklebur in cigar-wrapper tobacco shades in the area.

Soybean looper

Significantly greater numbers of larvae of the soybean looper were found on soybeans than on other crops in the 1-acre shade (Fig. 7b). Also greater numbers of larvae of soybean looper were found on soybeans than on other crops in the 8-acre system (Table 2). However, relative to crops other than soybeans in the system, high numbers of soybean looper were found on tomatoes and peanuts in the 8-acre system (Table 5). Relatively high numbers were also found on tomatoes and collards in the 1-acre shade (Fig. 7b). In addition, extremely light infestations of soybean looper were found on collards and bell peppers in the 8-acre system and on bush beans and cabbage in the 1-acre shade.

In the small cage test, significantly more eggs of the soybean looper were found on cocklebur and tomato than on soybeans and the other crops (Fig. 7b). This may have been due to differences in the condition of the plants, but relatively high numbers of larvae were also found in tomatoes in the 1-acre shade and in the 8-acre system. Therefore, plants such as tomato, cocklebur, and peanut appear to be relatively attractive as hosts for the soybean looper, but soybeans appeared to be the preferred host in my tests. At any rate, concentrated plantings of crops such as soybeans, tomatoes, and peanuts could influence populations that might occur on less attractive hosts such as tobacco, bell peppers, bush beans, or collards. Also, concentrations of cocklebur could influence the degree of infestation of the soybean looper in any of the host crops and, therefore, should perhaps be controlled.

The soybean looper and cabbage looper were the predominant species of Plusiinae found in the 8-acre system, however, a complex of Plusiinae occurred within the system, including Argyrogamma verucca (F.), Autographa biloba (Stephens), Rachiplusia ou (Guenee) and Trichoplusia oxygramma (Geyer) (Table 2). A. verucca was found primarily on field peas, but a few were found on soybeans, peanuts, bell peppers, and okra. A. biloba[4] was found only on white clover and T. oxygramma occurred only on field peas whereas R. ou[4] was found on white clover and collards. Since all of the Plusiinae species appear similar in the larval stage, it is likely that numerous mis-identifications have resulted from field identifications of the complex.

Tobacco budworm

Tobacco, okra, and white clover were the hosts most utilized by tobacco budworm in our tests. In the 1-acre shade, larvae were found only on cigar-wrapper tobacco, tomatoes, and bell peppers (Fig. 7c), but cigar-wrapper tobacco appeared to be the preferred host. However, results from the small cage test showed significantly greater numbers of eggs on tomatoes (84%) than the other crops, although 11% of the eggs were deposited on tobacco. Bush beans, soybeans, bell peppers, and cocklebur received the remaining 5% of eggs deposited in the small cage.

In the 8-acre cropping system, more larvae were found on flue-cured tobacco than any of the other crops (Table 6), but substantial infestations were found on cigar-wrapper tobacco, okra, and white clover. Okra became heavily infested only after tobacco was removed from the system. Also, light infestations were found on cabbage, collards, tomatoes, and peanuts.

[4]Both A. biloba and R. ou (mostly R. ou) were found also on crimson clover growing near the 8-acre system in 1973.

Fig. 7c presents the relationship of numbers of tobacco budworms found on the 7 crops which were also tested in the 1-acre shade and small cage. Cigar-wrapper tobacco was by far the most highly infested.

These results suggest that tobacco was the preferred host of the tobacco budworm among the crops tested, but alternate hosts such as okra and tomatoes were quite attractive during certain periods, especially when tobacco was absent from the system. Also, white clover was an attractive host and may function as an important alternate host in the early spring and fall in the absence of more attractive plants, such as tobacco and okra, and possibly tomatoes.

There were, of course, many variables in our tests such as prior insect damage, physical conditions of plants, degree of destruction by natural enemies, etc., that may have affected the intrinsic attractiveness of the host plants to the tobacco budworm and the other 2 noctuids. Radcliffe and Chapman (1966) stated that prior insect injury might have affected preferences of the cabbage looper in their studies. In the 1-acre shade both collards and cabbage were damaged extensively by the imported cabbageworm, Pieris rapae (L.), with collards generally possessing the highest numbers of this pest. However, despite this damage, these crucifers were still "preferred" for oviposition by cabbage loopers in my tests.

Pimentel (1961a) suggested differences in looper numbers in resistance investigations might sometimes be the results of differences in natural enemy destruction rather than differences in oviposition by the species tested. In the 1-acre shade and 8-acre system, parasitism of lepidopterous eggs was generally higher in tomatoes than in other crops. However, like Plusiinae larvae, in all 3 of my test areas numbers of

Plusiinae eggs were very low in tomatoes especially when compared to numbers in crucifers. Also, numbers of eggs of Heliothis spp. in the 8-acre system were very low in tomatoes relative to numbers in tobacco. In the 1-acre shade the proportion of all eggs of Heliothis spp. collected that were found in tomatoes was substantially lower than but still similar to the proportion of total larvae collected that were found in this crop.

In their investigations on resistance within crucifers, Harrison and Brubaker (1943) concluded that differences in numbers of loopers supported by the various crucifers was due to variation in the general physical condition of the crucifers. This certainly affected our results to some degree. However, despite the effects of such variability and the small number of reported hosts of these pests which were used in these investigations, some trends were indicated.

Even though densities of tobacco budworm and cabbage looper were quite high in all test areas, they selected a narrow range of hosts. Soybean looper densities were much lower than the other test species, but the soybean looper also selected a narrow host range.

Summary

Cabbage loopers increased rapidly in the spring to high densities in collards and cabbage in the 8-acre cropping system. This pest was found during most months of the year on collards and reached its highest densities in May, June, and September. When collards and cabbage were removed or appeared to be relatively unattractive, the cabbage looper hardly utilized other hosts in the cropping system. Cabbage loopers were not found on wild hosts. Catches in cabbage looper pheromone-baited blacklight (BL) traps were positively correlated with the number of

immatures in the field in 1972 but not in 1973. Collards and cabbage were the preferred hosts of the cabbage looper in 3 different test areas although several plant species served as incidental hosts.

Soybean loopers were found infrequently in the 8-acre cropping system from June through October. They generally occurred in soybeans, but were also found at relatively high density levels in tomatoes and peanuts. Cabbage looper pheromone-baited BL trap capture data were indicative of immatures of the pest in the 8-acre cropping system. Tests indicate soybeans were preferred as a host over a number of other crops, although tomatoes, cockleburs, and peanuts also appear to be attractive.

Tobacco budworm had rates of increase comparable to that of the cabbage looper and increased primarily on tobacco in the 8-acre system. However, a complex of hosts were important in the population dynamics of tobacco budworm in the system. In the early spring, low densities of the tobacco budworm were found on crimson clover, white clover, flue-cured and cigar-wrapper tobacco, and a few larvae were collected from venus lookingglass, tomatoes, cabbage, and collards. In the early and mid-summer months, tobacco was the primary host although some were also found from okra, prickly sida, peanuts, millet, and soybeans. The primary late-season host was okra and it served as the host from which most tobacco budworms in the 8-acre system went into diapause. Other late season hosts included small flower morningglory, beggarweed, and white clover. Tobacco budworms were active in the 8-acre system from early or mid-April through October. Prediction of occurrence and densities of immatures by utilizing data from BL traps and pheromone-baited grid traps appeared promising. Host preference studies indicated tobacco was preferred by the tobacco budworm over a number of crops but that okra, tomatoes, and white clover are also attractive to this species.

SECTION III

PARASITOIDS AND PATHOGENS

In 1912, Pierce et al. recognized the important and integral role of parasitoids and predators in the population dynamics of the boll weevil, Anthonomus grandis Boheman. They presented a novel diagram of this curculionid, its parasitoids and predators, and its interrelationships with other species, including the cotton plant, other pests, and hyperparasitoids.

Allee et al. (1949) felt that this paper was particularly unique in the field of synecology because of its constant emphasis on interspecific relationships. Since then, the importance of natural enemies in suppressing many insect pests has been well documented (Hagen et al. 1971; MacPhee and MacLellan 1971; Rabb 1971).

After artificial suppression of their natural enemies, numerous lepidopterous species can surge to pest status in many crops (Smith and van den Bosch 1967; Reynolds 1971; Smith and Reynolds 1972; van den Bosch and Messenger 1973). The cabbage looper (Falcon et al. 1968; Ehler et al. 1973), the soybean looper (Neal 1974), and the tobacco budworm (Ridgway et al. 1967; Lingren et al. 1968a; Newsom 1972; van Steenwyk et al. 1975) are, in many situations, examples of pests that have acquired importance following elimination of natural enemies.

Parasitoids and pathogens are an important part of the natural enemy complexes of many lepidopterous species (DeBach 1964, 1974; Huffaker 1971). Egg parasitoids such as trichogrammatids destroy a large portion of many

populations of lepidopterous pests even before they begin feeding on their hosts (van den Bosch and Hagen 1966). Some larval parasitoids destroy their hosts in early instars and may prevent immediate damage to crops, but most act through reduction in the breeding population of the next host generation and may thereby prevent pest populations from increasing to injurious levels (Elsey and Rabb 1970; Rabb 1971)

Most pathogens work in the latter manner by decimating lepidopterous populations that have reached high densities. Generally, pathogens do not effectively suppress population densities until the host population has been stressed (e.g., by weather, another pathogen) (Burges and Hussey 1971). DeBach (1974) stated: "Of those purposely imported, I know of no case where a pathogen alone has produced outstanding biological control at low levels but certain viruses have played a prominent role."

In the 8-acre cropping system there was something destroying many cabbage loopers, tobacco budworms, and soybean loopers between the egg stage and large larval stage (Section II). In this portion of the study into the population dynamics of the cabbage looper, soybean looper, and tobacco budworm, I obtained information on the role of parasitoids and pathogens in suppressing and regulating population numbers of these pests. Concerning parasitoids I attempted to: 1) identify the major and minor parasitoids of the cabbage looper, soybean looper, and tobacco budworm, 2) determine the seasonal occurrence of these parasitoids, 3) investigate interrelationships with their hosts and host-habitat, and 4) determine to some extent the impact of the parasitoids on the populations of the 3 pests.

For pathogens I attempted 1) to determine what the major agents of disease were. And 2) I attempted to measure seasonal occurrence of disease in the populations of cabbage loopers, soybean loopers, and tobacco budworms.

Literature Review

Cabbage Looper

Parasitoids

Ecological and biological studies designed to ascertain the significance and importance of parasitism and parasitoid species in suppressing and regulating the cabbage looper have been conducted in crucifers (Oatman 1966; Oatman and Platner 1969), some wild hosts of cabbage looper, alfalfa, tree tobacco, Nicotiana glauca (Clancy 1969), lettuce (Oatman and Platner 1972), and cotton (Ehler et al. 1973) in southern California, crucifers in New York (Sutherland 1966), and collards in North Carolina (Elsey and Rabb 1970). At least 50 parasitoid species have been recovered from field-collected cabbage loopers (Table 8). As many as 7 additional species may be represented in collected material that has been questionably identified. Three species complete development in eggs of cabbage looper and at least 45 utilize various larval instars. Two parasitoids are frequently recovered from pupae of cabbage looper. Some (especially tachinids) may be carried over from host larvae to host pupae.

Parasitoids such as Trichogramma spp., some Apanteles spp., and Meteorus autographae Muesebeck kill their host early in its life cycle, hence, generally preventing major crop damage by an individual host. Others, such as Voria spp., Eucelatoria armigera (Coquillett), and Lespesia archippivora (Riley) may do little to prevent feeding by the host, but could help cause a reduction in densities in subsequent generations of the host.

Several of the parasitoid species listed in Table 8 are not widespread in distribution and appear to be incidental records. Other generally attack other hosts, and may not be of major importance in the

Table 8.--Parasitoids of cabbage looper found in field studies in the United States.

Stage attacked	Parasitoid species	References
Egg	Trichogrammatidae	
	Trichogramma evanescens Westwood	Oatman et al. (1968)
	T. minutum Riley	McKinney (1944)
	T. pretiosum (Riley)	Oatman (1966)
Larval and/or pupal	Braconidae	
	Apanteles autographae Muesebeck	Muesebeck and Krombein (1951)
	A. congregatus (Say)	Riley (1893)
	A. glomeratus (L.)	Chittenden (1902)
	A. laeviceps Ashmead	Muesebeck and Krombein (1951)
	A. marginiventris (Cresson)	Boling and Pitre (1971)
	Apanteles sp.	Butler (1958a)
	Chelonus blackburni Cameron	Fye and Jackson (1973)[a]
	C. texanus Cresson	Ehler et al. (1973)[a]
	Meteorus autographae Muesebeck	Muesebeck and Krombein (1951)
	Microplitis alaskensis Ashmead	Butler (1958a)
	M. brassicae Muesebeck	McKinney (1944)
	M. plutellae Muesebeck	Oatman and Platner (1969)
	Rogas granulatus DeGant	DeGant (1930)
	R. molestus Cresson	Butler (1958a)
	R. perplexus Gahan	Butler (1958a)
	R. rufocoxalis Gahan	McKinney (1944)
	Rogas sp.	Wall and Berberet (1975)
	Chalcididae	
	Brachymeria ovata (Say)	Elsey and Rabb (1970)
	Encyrtidae	
	Copidosoma truncatellum (Dalman)	Riley (1883)[a]
	Eulophidae	
	Euplectrus comstockii Howard	McKinney (1944)
	Euplectrus platyhypenae Howard	Wall and Berberet (1975)
	Pediobus sexdentatus (Girault)	Oatman and Platner (1969)
	Tetrastichus rapo (Walker)	Peck (1963)
	Ichneumonidae	
	Coccygominus aequalis (Provancher)	Sutherland (1966)
	Diadegma insulare (Cresson)	Hayslip et al. (1953)
	Diadegma spp.	Sutherland (1966)
	Gambrus ultimus (Cresson)	Sutherland (1966)
	Gelis terellus (Say)	Sutherland (1966)
	Hyposoter exiguae (Viereck)	Oatman (1966)
	Iseropus stercorator orgyiae (Ashmead)	Sutherland (1966)
	Itoplectis conquisitor (Say)	Muesebeck and Krombein (1951)
	Netelia sp.	Watson et al. (1966)
	Patrocloides montanus (Cresson)	Clancy (1969)
	Pterocormus gestuosus (Cresson)	Mitchell (1961)
	Stenichneumon culpator cincticornis (Cresson)	Schaffner and Griswold (1934)
	Vulgichneumon brevicinctor (Say)	Muesebeck and Krombein (1951)
	Sarcophagidae	
	Sarcodexia sternodontis Townsend	Aldrich (1927)
	Tachinidae	
	Archytas californiae (Walker)	van den Bosch and Hagen (1966)
	Compsilura concinnata (Meigen)	Schaffner and Griswold (1934)
	Eucelatoria armigera (Coquillett)	Butler (1958b)
	E. rubentis (Coquillett)	Watson et al. (1966)
	Eusisyropa blanda blanda (Osten Sacken)	West (1925)
	Lespesia archippivora (Riley)	Watson et al. (1966)
	Lespesia sp.	Clancy (1969)
	Madremyia saundersii (Williston)	Oatman (1966)
	Periscepsia helymus (Walker)	Clancy (1969)
	Phorocera sp.	Sutherland (1966)
	Phryxe vulgaris (Fallén)	Sutherland (1966)
	Siphona plusiae Coquillett	Clancy (1966)
	Siphona sp.	Oatman (1966)
	Voria aurifrons (Townsend)[b]	Wall and Berberet (1975)
	V. ruralis (Fallén)	Schaffner and Griswold (1934)
	Winthemia quadripustulata (F.)	Allen (1925)
	W. rufopicta (Bigot)	Schaffner and Griswold (1934)
	Winthemia spp.	Elsey and Rabb (1970)

Note: Brachymeria intermedia (Nees)(Peck 1963) and Campoletis sonorensis (Cameron)(Lingren et al. 1970) were recovered from cabbage loopers exposed to these parasitoids in the laboratory.

[a]Parasitoid oviposition is in the host eggs.

[b]According to C. W. Sabrosky, Systematic Entomology Laboratory, Beltsville, MD (personal communication), V. aurifrons probably is a synonym for V. ruralis.

population dynamics of the cabbage looper. Ten to 13 parasitoid species are the largest numbers reported from several studies on their abundance in populations of the cabbage looper (Oatman 1966; Sutherland 1966; Oatman and Platner 1969; Clancy 1969); in most other publications, 5 or fewer parasitoids are mentioned.

Trichogramma pretiosum, Copidosoma truncatellum (Dalman), and Voria ruralis (Fallen) appear to be the major and most widespread parasitoids of the cabbage looper; they are frequently mentioned in the literature as being very important population suppression agents on many crops and in numerous areas of the United States. Several other parasitoids are sometimes numerous in certain areas and may be important in suppressing population densities of the cabbage looper. For instance, Hayslip et al. (1953) reported that Diadegma insulare (Cresson) was important in reducing numbers of cabbage looper on south Florida crucifers.

Sutherland's (1966) research indicated that Stenichneumon culpator cincticoris (Cresson) and Vulgichneumon brevicinctor (Say) might be important regulators of cabbage looper on occasion in New York. In the western U.S., Microplitis brassicae Muesebeck, E. armigera, L. archippivora, and Hyposoter exiguae (Viereck) are apparently important parasitoids of the cabbage looper (Butler 1958ab; Oatman 1966; Clancy 1969, Oatman and Platner 1969; and Ehler et al. 1973).

Some native parasitoid species may not be widespread in the U.S., nor often cause high mortalities in cabbage looper populations, but could occasionally cause population numbers of cabbage looper to collapse because they destroy the residue of a population already seriously depleted by other mortality factors. In North Carolina Elsey and Rabb (1970) concluded that Brachymera ovata (Say) might act as such a mortality factor

on the cabbage looper in some seasons.

Parasitism of cabbage looper eggs is very important in crop protection, since the cabbage looper is destroyed before it can feed. Parasitism of cabbage looper eggs is almost exclusively by Trichogramma spp. and T. pretiosum appears to be the species most commonly recovered from cabbage looper eggs. McKinney (1944) found Trichogramma spp. had parasitized up to 47% of the cabbage looper eggs he collected from lettuce in Arizona one year, and Trichogramma spp. have frequently been recovered from cabbage looper eggs in studies in California (Oatman 1966; Oatman et al. 1968; Oatman and Platner 1969, 1972).

In crucifers, parasitism of cabbage looper eggs by Trichogramma spp. was generally lower than 20% during studies by Oatman et al. (1968). But in tomatoes, Trichogramma spp. were frequently observed to destroy at least 40% of the cabbage looper eggs collected in studies by Graham (1970) and Oatman and Platner (1971). In many crops, estimates of parasitism of cabbage looper larvae has often been higher than those for egg parasitism, probably because of longer exposure of the larvae to a variety of parasitoid species. McKinney (1944) stated that "larval parasites seem to be more uniformly distributed from field to field than do the egg parasites and exercise a more effective control against the looper."

Oatman (1966) collected 1,737 cabbage looper larvae from California crucifers; 26% of the larvae were parasitized, mostly by tachinids. On 2 dates, over 90% of the larvae collected were parasitized. V. ruralis and C. truncatellum were the primary parasitoids recovered, but 7 others were also considered to be of importance.

Oatman and Platner (1969) later found additional evidence that larval parasitism was an important mortality factor of cabbage looper on cabbage

in southern California, but mortality was often low during the summer months. V. ruralis, the dominant parasitoid of 12 species recovered, was most frequently found in the fall and winter. H. exiguae and C. truncatellum occurred most commonly during the summer and fall.

Clancy (1969) found similar trends of parasitism from collections of larvae from wild hosts, alfalfa, and tree tobacco in California with the total larval parasitism being highest (41%) in tree tobacco. Larval parasitism was greater (over all crops and wild hosts) from August-January than during other periods of the year. McKinney (1944), Butler (1958b), and Brubaker (1968) found V. ruralis was the most common parasitoid of cabbage looper larvae collected from weeds and cultivated crops in Arizona, and that it was most abundant during late fall and winter.

Pathogens

Relative to those conducted on parasitoids, few seasonal field surveys have been conducted to quantitatively determine the importance of pathogens in suppressing and regulating population numbers of the cabbage looper (or the soybean looper and tobacco budworm). Hofmaster (1961) did, however, monitor the incidence of nuclear polyhedrosis virus (NPV) on cabbage near Pointer, VA, and Semel (1956) and Sutherland (1966) reported on NPV occurring in cabbage looper populations in New York.

From collections of Plusiinae, probably primarily cabbage looper, in cotton fields in Alabama, Harper and Carner (1973) did not find much incidence of disease until early August. Eight percent of the Plusiinae larvae collected were diseased with Entomophthora sp., 2% with Nomuraea (= Spicaria of authors) sp., and 41% with NPV.

NPV has been considered to be a very important mortality agent for many years (Chapman and Glaser 1915). It is the most obvious pathogen

of loopers which reach high densities in crops such as crucifers and cotton (Creighton 1973).

Other pathogens that have been found in and isolated from cabbage loopers are Nosema trichoplusiae (Tanabe and Tamashiro 1967), cytoplasmic polyhedrosis viruses, granulosis viruses, Spicaria prasina (Burges and Hussey 1971), Bacillus thuringiensis (Cameron 1971), Nomuraea rileyi, Entomophthora megasperma, Beauvaria bassiana, Aspergillus flavus, Penicillium sp. (Thomas and Poinar 1973), Entomophthora sphaerosperma (Yendol and Paschke 1967), and Metarrhizium anisopliae (Creighton 1973).

Soybean Looper

Parasitoids

Much less is known about the soybean looper than the cabbage looper since it is not as economically serious a pest (Section II). However, Burleigh (1971, 1972) did study the parasitoid complex which affected the soybean looper in 3 cropping systems in Louisiana. He found parasitism by parasitoids can be an important regulatory factor in the population dynamics of the soybean looper.

Prior to Burleigh's studies, Janes and Greene (1970) found 9% of the soybean looper larvae they collected from sweet corn ears were parasitized by C. truncatellum. Another 8% were destroyed by a small unidentified Hymenoptera.

Burleigh (1971) found 7 parasitoids from soybean looper larvae: C. truncatellum, M. autographae, Apanteles scitulus Riley, Lespesia aletiae (Riley), B. ovata, Rogas molestus Cresson, and Mesochorus sp. (a hyperparasitoid). C. truncatellum, the most common parasitoid, occurred throughout the sampling period, but was most abundant from mid-July to late August. L. aletiae was also a significant mortality factor (Burleigh 1972).

A. scitulus was also abundant, particularly in June and July, and in 1 area was the major parasitoid (Burleigh 1971). During 1 year, many A. scitulus were parasitized by Mesochorus sp.

Percent parasitism of total collected larvae ranged from 3.7 - 46.3% (Burleigh 1971). Generally parasitism declined in each successive generation of the soybean looper occurring during a year, particularly when incidence of a fungal pathogen, Nomuraea rileyi increased. Parasitism was lower in a "cotton and soybean ecosystem" (where soybean looper density was the highest) than in a "rice ecosystem" and in a "cleared hardwood forest ecosystem" (Burleigh 1972). Parasitism by parasitoids was the major mortality factor in the 1st generation of the soybean looper, but it was less noticeable in subsequent generations.

Pathogens

Harper and Carner (1973) felt a rapid decline in soybean looper population densities in late August in Alabama soybeans was principally due to pathogens since the major parasitoid, C. truncatellum, parasitized few larvae (<1%) and few predators were observed. They found peaks in incidence of disease in soybean looper populations occurred in early August and September. In contrast to the cabbage looper in cotton, none were diseased with NPV, but a few were diseased with Nomuraea sp., and 35% of the soybean looper larvae collected in 1 field survey were diseased with Entomophthora sp.

Like Burleigh (1971), Gudauskas and Canerday (1966) determined N. rileyi to be a pathogen of soybean looper. Also, from diseased soybean looper larvae collected from cotton, peanuts, and soybeans in Alabama, Watson et al. (1966) isolated N. rileyi and a bacterium, Streptococcus sp. from soybean loopers.

Tobacco Budworm

Parasitoids

The importance of parasitoids in regulating tobacco budworm population numbers has been recognized by numerous authors (Chamberlin and Tehnet 1926a; Morgan and Chamberlin 1927; Wene 1943; Grayson 1944; Wille 1951; Noble and Graham 1966; van den Bosch and Hagen 1966; Lewis and Brazzel 1966b; Lewis and Brazzel 1968; Rabb 1971; Ridgway and Lingren 1972). Some of the major parasitoids which have been recovered from tobacco budworm are presented in Table 9. Most work on parasitoids of the tobacco budworm occurred in tobacco and cotton, the primary hosts of the tobacco budworm, but several studies have also been conducted on wild host plants.

The several papers published on Cardiochiles nigriceps Viereck have yielded considerable information on the seasonal occurrence of this parasitoid. Chamberlin and Tehnet (1926a) usually detected C. nigriceps at Quincy in the spring soon after the tobacco was planted. This braconid was numerous from May until September. In July and August, 3-4 adults of C. nigriceps were frequently seen flying around a single stalk of tobacco by Chamberlin and Tehnet (1926a). In cage tests, C. nigriceps emerged from overwintering diapause during a period of March 20 - September 11 and adults were found as late as November 3.

C. nigriceps occurred in Virginia tobacco from late June to late August (Grayson 1944). Snow and Burton (1967) found C. nigriceps in beggarweed in Georgia from August 11 - September 1. It was reared from larvae collected from Abutilon trisulcatum in the Rio Grande Valley during October 27 - November 2 when 56.3% of the larvae collected were parasitized, and November 4-10 when 13.3% of the larvae were parasitized (Graham et al.

Table 9.--Major parasitoids of the tobacco budworm found in the United States.

Stage attacked	Parasitoid species	References
Egg	Trichogrammatidae	
	Trichogramma spp.	Muesebeck and Krombein (1951)
	Trichogramma pretiosum Riley	Oatman and Platner (1971)
	T. semifumatum Perkins	Graham (1970)
Larval and/or Pupal	Braconidae	
	Apanteles marginiventris (Cresson)	Muesebeck and Krombein (1951)
	Bracon mellitor Say	Neunzig (1969)
	Cardiochiles nigriceps (Vierick)	Chamberlin and Tehnet (1926a)
	Chelonus texanus (Cresson)	Ridgway and Lingren (1972)
	Microplitis croceipes (Cresson)	Watson *et al.* (1966)
	Ichneumonidae	
	Campoletis sonoresis (Cameron)	Wene (1943)
	Netelia sp.	Nuenzig (1963)
	Pristomerus pacificus melleus Cushman	Nuenzig (1969)
	Tachinidae	
	Archytas marmoratus (Townsend)	Watson *et al.* (1966)
	Eucelatoria armigera (Coquillett)	Jackson *et al.* (1969)

1972). Neunzig (1969) found larvae parasitized by C. nigriceps in tobacco, cotton, and deergrass from May 26 - October 10.

Another parasitoid of the tobacco budworm about which there is limited information on seasonal abundance, is Campoletis sonorensis (Cameron). In North Carolina parasitism by this icheumonid was reported to be >70% from late May until late July in tobacco (Rabb 1971). From early July to mid-October substantial parasitism by C. nigriceps occurred and parasitism by C. sonorensis was generally low. In late October and early November, C. sonorensis was the only parasitoid found.

Egg parasitoids of tobacco budworm are important in crops such as tomatoes (Graham 1970) and cotton (Lingren 1969). Graham (1970) found a large percentage of tobacco budworm eggs on tomatoes were attacked by Trichogramma semifumatum Perkins, but rarely has egg parasitism been observed on tobacco (Rabb and Bradley 1968; Gentry et al. 1973). Rabb and Bradley (1968) suggested that eggs on tobacco are not parasitized because of the sticky surface of a typical tobacco leaf.

Larval parasitoids are much more effective on tobacco than are egg parasitoids. In southeastern U.S. tobacco, Cardiochiles nigriceps has generally been the most common parasitoid. Chamberlin and Tehnet (1926a) often found that during July and August, 50-100% of tobacco budworms collected in tobacco were parasitized. Grayson (1944) estimated 15-43% parasitism by C. nigriceps in various lots of tobacco budworm collected in Virginia tobacco.

Parasitism by C. nigriceps in Snow and Burton's (1967) field of beggarweeds ranged from 0-34%. Neunzig (1963) found that 50% of the tobacco budworm larvae collected on deergrass in August of 1958 were parasitized by C. nigriceps, but only 5% were parasitized in 1961.

Later Neunzig (1969) reported parasitism by C. nigriceps of tobacco budworms collected on various dates in various fields of tobacco ranged from 11.5 - 94.0%. In cotton parasitism of tobacco budworms by C. nigriceps ranged from 0-100%. No C. nigriceps were recovered from tobacco budworms collected in toadflax during the period of April - June and few were found from those collected in deergrass from July - September.

Campoletis sonorensis is also commonly mentioned in the literature as an important parasitoid of tobacco budworm. Wene (1943) found that C. sonorensis parasitized from 14 - 94% of the tobacco budworms collected in tobacco fields and plant beds in Virginia. Tobacco budworm larvae in the sampled fields were rarely larger than 3rd-instar. Grayson (1944) estimated parasitism at 15 - 43% by this species in Virginia tobacco.

In their studies on wild host plants of Heliothis spp., Graham et al. (1972) found Campoletis sp. (which accounted for 76% of the parasitoids identified) and Micropletis croceipes (Cresson) to be the most common parasitoids of tobacco budworms on wild tobacco and Ruellia runyonii. Parasitization of tobacco budworms on wild tobacco was 20 - 41% from March 10 - May 21. On R. runyonii it was 0-59% from April 28 - August 31. Watson et al. (1966) found parasitism of tobacco budworms to be higher on beggarweed than on other hosts, but "the parasite involved was the ichneumonid, Netelia sp. . . ."

Numerous other studies of Heliothis spp. on cotton and other crops contains an abundance of information on parasitoids of the tobacco budworm (Ridgway and Lingren 1972). Apanteles marginiventris (Cresson) and Microplitis croceipes appear to be 2 other species that are particularly important suppressants of tobacco budworm densities.

Pathogens

In their studies of pathogens and other natural enemies of the tobacco budworm, Watson et al. (1966) isolated Aspergillus flavus, Penicillium sp., Rhizopus sp., Nomuraea (= Spicaria of authors) sp., other bacteria, and a suspected virus from diseased tobacco budworms. Nosema heliothidis has also been isolated from tobacco budworms (Burges and Hussey 1971). Like the cabbage looper, Heliothis spp. also suffer from infections caused by NPV but the NPV of Heliothis spp. "is not so highly virulent as that of the cabbage looper" (Dulmage 1972).

Methods and Materials

Collections of eggs and larvae of cabbage looper, soybean looper, and tobacco budworm, and other Plusiinae, corn earworm, and several other Lepidoptera, were made in the 8-acre cropping system, and adjacent or nearby wild hosts, as was reported in Section I. These were taken in order to monitor parasitism and incidence of disease acting on the populations of cabbage looper, soybean looper, and tobacco budworm discussed in Section II. Collected eggs and larvae were checked at 3-4 day intervals for parasitoids, and for disease (Burges and Hussey 1971).

Egg parasitism was determined under a stereo-dissecting scope by noting the presence of the blackened appearance of the shell produced by Trichogramma spp. or finding adult parasitoids in the containment area. Larval parasitism was determined by emergence of parasitoid adults or presence of parasitoid larvae in the lepidopterous larvae after death of the host larva was observed. Records of parasitism and other records were kept on the "egg cards" or larval cup tops until all information desired was obtained. Those larvae which appeared to die of starvation

were not used in calculating parasitization or disease.

I removed egg and larval parasitoids from the cups and cards as they developed to the adult stage and either "pinned" them or placed them in small glass vials of ca. 70% ethanol. In 1973 I removed parasitized (blackened) eggs from the tape-made-cells and placed them in small clear gelatin capsules (size 000) in order to prevent parasitoids emerging from eggs from becoming entangled in the sticky tape. After collections were made most larval parasitoids were sent to E. E. Grissell, Div. Plant Industry, Gainesville, FL and most egg parasitoids were eventually sent to S. Nagarkatti, CIBC, Bangalore, India for identification.

Lepidoptera collected in the 8-acre system, in addition to Plusiinae and Heliothis spp., included velvetbean caterpillar, Anticarsia gemmatalis Hubner, green cloverworm, imported cabbageworm, fall armyworm, Spodoptera frugiperda (Smith), tobacco hornworm, Manduca sexta (L.), diamondback moth, Plutella xylostella (L.), Anomus sp., Prodenia sp., and Agrotis sp. Velvetbean caterpillars were collected from a number of crops, but eggs were especially numerous in 1972 in field peas, during August and September, and in white clover, during September, October, and November, and relatively large samples were taken. Relatively large samples of larvae of green cloverworm were taken in 1973 in white clover, during February and early March, when they were numerous in this crop. Fall armyworms were most numerous in May and early June of 1973 in field corn, and relatively large collections of this pest was made. High numbers of imported cabbageworm eggs were collected during several periods during the spring, summer, and fall in collards.

In addition to collections of wild material, laboratory-reared cabbage looper eggs were introduced into the 8-acre cropping system on

several dates during the summer of 1972 by placing the eggs individually on plants of the system with egg albumin as a sticker (Whitcomb and Bell 1964), or by pinning masses of eggs that were oviposited on paper towels to plants in the cropping system. These were collected after 24-48 hr in the system, but recovery of eggs was very low, presumably because of predation.

Additional monitoring for the presence of Trichogramma spp. and other egg parasitoids were undertaken in 1973 in the 8-acre cropping system. Two to 4 potted tomato plants bearing eggs of laboratory-reared tobacco budworms were placed within various crops of the 8-acre system on several dates in March, April, and May, and collected 24-48 hr later. Tobacco plants possessing tobacco budworm eggs were also placed in crops of the 8-acre cropping system to further substantiate that parasitoids avoided ovipositing in host eggs laid on this plant.

Collections of eggs and larvae of Plusiinae and Heliothis spp. were also made in the 1-acre shade (Section I) in order to monitor parasitism and disease. Some of these data were used for development of this section. Methods were similar to those for the 8-acre system.

Although the only index provided from my studies of abundance of most of the parasitoids, was the rate of parasitism of the immature Lepidoptera collected, abundance of Cardiochiles nigriceps adults was measured on one date (July 7, 1972) by 3 methods. First, the presence or absence of C. nigriceps adults on or near 50 tobacco plants were recorded. Second, the number of C. nigriceps adults per plant on 20 randomly selected plants was recorded. Third, the number of C. nigriceps that visited a plant during one minute was recorded for 5 plants.

Results and Discussion

Parasitoids

Parasitoids recovered from Lepidoptera collected in the 8-acre cropping system are presented in Table 10. At least 11 parasitoids were collected from cabbage loopers, and 7 were relatively common.

Six different parasitoid species were collected from soybean loopers with each being about equally common. Four were species reared from the cabbage looper; however, the tachinids, Lespesia aletiae and Chaetophlepsis townsendi (Smith) were not recovered from Plusiinae thought to be cabbage loopers.

At least 6 parasitoids were collected from the tobacco budworms; however, Cardiochiles nigriceps was by far the predominant parasitoid. C. nigriceps, Campoletis sonorensis, Telenomus heliothidis Ashmead, and Netelia sp. were collected only from Heliothis spp. which may have all been tobacco budworms. I did not note Trichogramma fasciatum (Perkins) or Telenomus heliothidis Ashmead recovered from tobacco budworm, Trichogramma fasciatum (Perkins) or Trichogramma perkinsi (Girault) recovered from cabbage loopers, or Chaetophlepsis townsendi, Apanteles marginiventris, or Trichogramma pretiosum recovered from soybean loopers, in the literature I reviewed.

Although Copidosoma truncatellum, Voria ruralis, and Cardiochiles nigriceps were relatively stenophagous parasitoids, many of the parasitoids of Plusiinae and Heliothis spp. were oligophagous. For instance, T. pretiosum was discovered from eggs of Heliothis spp., Plusiinae, and at least 1 other lepidopterous species. A. marginiventris and M. autographae were found from Heliothis spp., Plusiinae, and several other lepidopterous species. T. perkinsi, Eucelatoria rubentis (Coquillett),

Table 10.--Parasitoids reared from immature cabbage loopers, soybean loopers, tobacco budworms, and other Lepidoptera collected from an 8-acre cropping system and in nearby wild hosts.

Host stages necessary for development	Parasitoid species	ex Plusiinae					ex Heliothis			ex others[a]
		spp.	Trichoplusia ni	Pseudoplusia includens	Rachiplusia ou	Argyrogramma verucca	spp.	virescens	zea	
Early stages										
Egg	Trichogrammatidae[b]									
	Trichogramma spp.	++	++	+		x	++	+	++	x
	Trichogramma pretiosum (Riley)	++	++	+			++	+	++	x
	T. semifumatum Perkins (=T. pretiosum?)[c]	++	++				++	+	++	x
	T. fasciatum (Perkins)	++	++				++	+	++	
	T. perkinsi (Girault)	+	+				+		+	x
	T. minutum Riley	-	-							x
	T. evanescens (Westwood)									x
	Trichogramma sp. 1?[d]	x								
	Trichogramma sp. 2?[e]									x
	Scelionidae									
	Telenomus heliothidis Ashmead									
	Telenomus sp.	-[f]					-	-		
	T. sphingis Ashmead									x
Larval	Braconidae									
	Meteorus autographae Muesebeck	++	++	+	++	x	++	+		x
	Apanteles marginiventris Cresson	++	++	+	+	x	++	+	x	x
	Rogas sp.						-			
	Ichneumonidae									
	Campoletis sonorensis (Cameron)						-	-		
	C. flavicincta (Ashmead)									x
Early and later stages										
Egg-larval	Encyrtidae									
	Copidosoma truncatellum (Dalman)	++	++	++	x					
	Braconidae									
	Cheloncus texanus Cresson									x
Larval or larval-pupal	Braconidae									
	Cardiochiles nigriceps Viereck						++	++		
	A. autographae Muesebeck	++	++		-					
	A. glomeratus (L.)									x
	A. congregatus (L.)									x
	Eulophidae									
	Euplectrus plathypenae Howard	-								
	Euplectrus sp.	-								x
	Ichneumonidae									
	Pristomerus pacificus malleus (Cushman)						+	+		x
	Netelia sp.						-	-		
	Ophion ancyloneura (Cameron)									x
	Ophion sp.									x
	Tachinidae									
	Voria ruralis (Fallén)	++	++							
	Eucelatoria rubentis (Coquillett)	+	+			+	+		+	
	Lespesia archippivora (Riley)	x	x				x		x	
	Lespesia aletiae (Riley)	++		++	x					x
	Chaetophlepsis townsendi (Smith)	++		++						x
	Chaetophlepsis sp.	x								x
	Archytas marmoratus (Townsend)						+		+	x

Table 10.--Continued

Host stages necessary for development	Parasitoid species	ex Plusiinae					ex Heliothis			ex others[a]
		spp.	Trichoplusia ni	Pseudoplusia includens	Rachiplusia ou	Argyrogramma verucca	spp.	virescens	zea	
Unknown[g]	Braconidae									
	Zele sp.									x
	Ichneumonidae									
	Syrophoctorus sp.									x
	Ventura nigriceps									x
	Diadegma insulare (Cresson)									x
	Pteromalidae									
	sp. of Pteromalidae	=								
	Eupteromalus sp.									x

Note: Based on data from Plusiinae and Heliothis spp. the symbols are used as follows: ++, commonly found in some seasons and crops; +, occasional; -, rare; =, very rare; x, not enough data to establish if rare, etc. None found from Trichoplusia oxygramma.

[a]Velvetbean caterpillar, green cloverworm, imported cabbageworm, fall armyworm, tobacco hornworm, diamondback moth, Anomus sp., Prodenia sp., or Agrotis sp.

[b]Determined by L. R. Ertle, Agr. Res. Serv., USDA, Newark, DE, and Sudha Nagarkatti, CIBC, Banglore, India.

[c]Determined by Sudha Nagarkatti, according to L. R. Ertle (letter dated 5 December 1972) "her" T. semifumatum is similar to "his" T. pretiosum.

[d]A new species according to L. R. Ertle (letter dated 5 December 1972).

[e]Possible new species described by L. R. Ertle (T. nubilalum Ertle) according to Sudha Nagarkatti (letter dated 20 January 1975).

[f]From 1 Plusiinae egg collected in the 1-acre shade.

[g]Or difficult to fit into upper categories.

Lespesia archippivora, Chaetophlepsis townsendi and Archytas marmoratus (Townsend) were all found from at least 2 different hosts.

Seasonal occurrence

Those parasitoids which were oligophagous (i.e. various Trichogramma spp., Meteorus autographae, and Apanteles marginiventris) were frequently collected, and were collected during most seasons of the year (Fig. 8). The records for M. autographae in January, February, and most in March, and for A. marginiventris in February, and most in March, were from green cloverworms collected in white clover. Most other records for these parasitoids were from Plusiinae or Heliothis spp. in various crops.

Trichogramma spp. were abundant in the 8-acre system from April to November (Fig. 8). The 1st eggs parasitized by Trichogramma spp. were not collected during each spring until April 7, 1972 or March 14, 1973 even though a number of potential host eggs were collected prior to these dates. Early records were from Plusiinae eggs in collards and Heliothis spp. eggs in tomatoes. In the fall parasitized eggs were collected as late as November from velvetbean caterpillar eggs in white clover. They were also found as late as October in Plusiinae eggs in collards, in velvetbean caterpillar eggs in field peas, and in Heliothis spp. eggs in tomatoes and squash.

Copidosoma truncatellum and V. ruralis were not oligophagous. But both were collected during all seasons of the year though the number of V. ruralis was relatively small. It may have been difficult for the latter species to increase because of the prevalence of nuclear polyhedrosis virus (NPV) within the cabbage looper population from about June through September. The polyembryonic C. truncatellum was perhaps more successful in competing with NPV. However, since C. truncatellum was recovered from all sizes of

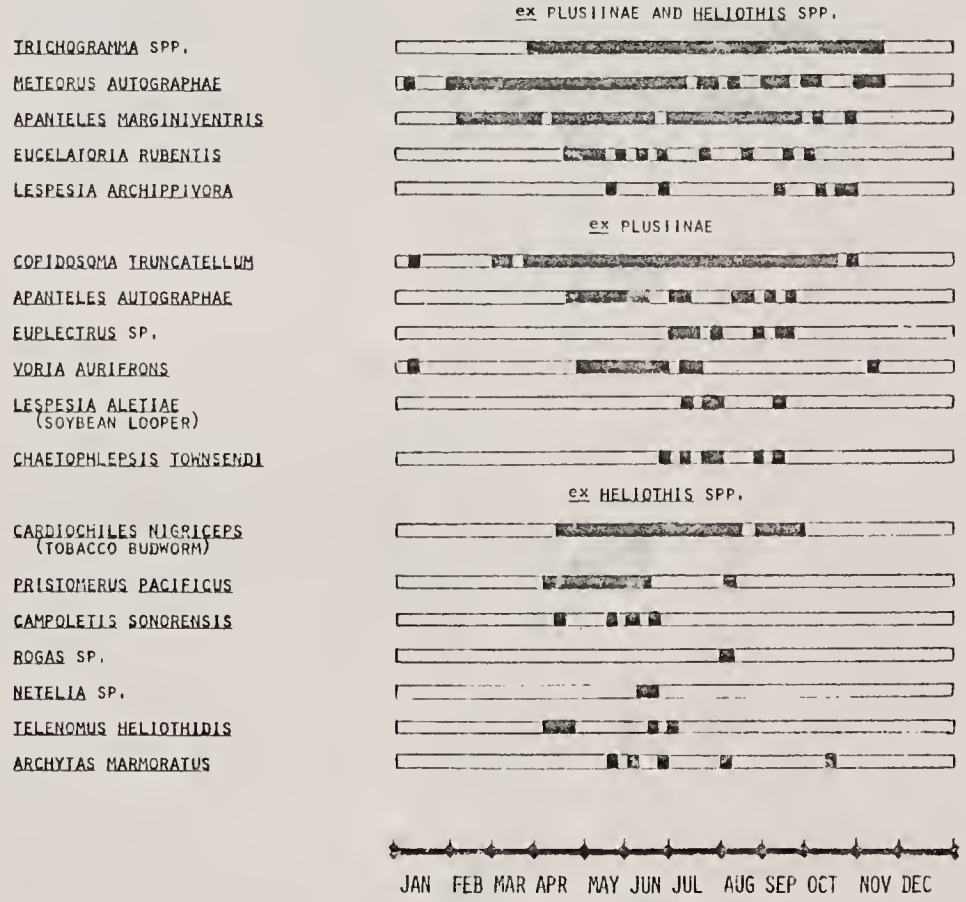

Fig. 8.--Seasonal occurrence of parasitoids of the cabbage looper, soybean looper, and tobacco budworm in an 8-acre cropping system and a 1-acre shade during 1971, 1972, and 1973. Samples were taken during 12 months in 1972, January through August in 1973, and August and September of 1971.

Plusiinae larvae collected, and V. ruralis was restricted mostly to collections of medium- to large-sized larvae, the probability of collecting C. truncatellum from cabbage looper larvae was also higher.

In the 8-acre system Apanteles autographae were collected from April through July in 1973, but was not collected in 1972. It was also found in the 1-acre shade from August through October (Fig. 8). This gregarious species may be less successful than C. truncatellum in finding hosts. However, once it does find the host-habitat, it does not need to search as extensively as the solitary species of Apanteles (i.e., A. marginiventris) in order to oviposit an equal number of eggs. Most larval parasitoids of Plusiinae other than A. autographae (i.e. Euplectrus sp., L. aletiae, and Chaetophlepsis townsendi) were found in the 8-acre system in late summer of both years (Fig. 8).

Seasonal occurrence of Eucelatora rubentis, Lespesia archippivora, and the other parasitoids collected mostly from Heliothis spp., were generally restricted to the period of April-October (Fig. 8) because Heliothis spp. were mostly in diapause from October-April. Campoletis sonorensis, Pristomerus pacificus melleus (Cushman), and Telenomus heliothidis were found only in the spring or early summer. Similar to the findings of Rabb (1971), C. sonorensis was found, although very infrequently, at highest numbers in May and June. However, it was not recovered from larvae collected in October and November nor most other months. During 1972, T. heliothidis emerged from 4 of 8 eggs of Heliothis spp. collected in tomatoes on April 12 and 17, but it was never again found from any egg of Heliothis spp. or Plusiinae in any crop during that year. Results were similar from eggs collected in 1973, although some T. heliothidis were found in June and July. Most eggs parasitized by T. heliothidis in 1973 were from tobacco budworm eggs on

tomato plants placed in crops of the 8-acre system.

Cardiochiles nigriceps were first collected in larvae of tobacco budworms on April 17, 1972 or April 18, 1973. These were collected from larvae found on white clover in 1972, and from larvae found on venus looking-glass in 1973. In 1972, adults of C. nigriceps were sighted in tobacco before tobacco budworm eggs or larvae were found in whole plant inspections in the system. Adults of C. nigriceps were estimated at >20,000 adults per acre in flue-cured tobacco during July. Intensive sampling on July 7, 1972 indicated presence of C. nigriceps on 88% of plants checked. An average of 1.8 adults were observed on a series of individual plants and a mean of 6.4 adults were seen to visit a second series of plants that were individually observed for 5 minutes. This is similar to the results of Chamberlin and Tehnet (1926a). Few C. nigriceps were collected from tobacco budworm larvae on any host plant after removal of tobacco from the system.

All C. nigriceps collected from larvae of the tobacco budworm in September in the 1-acre shade went into diapause in the cocoon stage. Also, some diapause was observed in specimens collected from tobacco throughout the summer in the 8-acre system. These diapausing individuals generally emerged the following spring and summer in the laboratory. In field cage tests Chamberlin and Tehnet (1926a) observed a similar pattern of emergence.

Host stages utilized

The egg stage of soybean looper, tobacco budworm, and cabbage looper was utilized primarily by Trichogramma spp. Only a few other parasitoids (Telenomus spp.) were collected from any lepidopterous eggs.

The small to medium-size category of larvae of cabbage looper, soybean looper, and tobacco budworm were parasitized by several parasitoids.

Apanteles marginiventris and Campoletis sonorensis were generally recovered from small larvae. Meteorus autographae were mostly recovered from small- to medium-sized larvae. Apanteles autographae generally emerged from medium-sized larvae.

Although they started their life cycle in a relatively early host stage, Copisosoma truncatellum, Cardiochiles nigriceps, Pristomerus pacificus melleus, and tachinids usually emerged from medium-sized larvae, large larvae, or pupae. C. truncatellum which oviposits in Plusiinae eggs (Oatman and Platner 1969) and Cardiochiles nigriceps which generally oviposit in small larvae (Neunzig 1969) were recovered from large larvae and prepupae. P. pacificus melleus emerged from medium- to large-sized larvae. Tachinids emerged from either large larvae or pupae.

Fig. 9-11 illustrates the parasitization rates and parasitoid complex found in various larval stages of cabbage loopers, soybean loopers, and tobacco budworms collected from the 8-acre system. Small, medium, and large larvae of cabbage loopers had similar rates of parasitism during most weeks in which cabbage loopers were collected in 1973 (Fig. 9).

The small-larvae category generally contained an array of parasitoids, but A. marginiventris and C. truncatellum were the most common ones. In the medium-sized category, diversity of parasitoids collected was somewhat less than that for the small-sized category. The most common parasitoids from medium-sized larvae were C. truncatellum and M. autographae. C. truncatellum and tachinids were the most common parasitoids collected from large larvae. Tachinids were probably particularly important in regulating cabbage looper densities since they parasitize many of the medium- to large-sized larvae remaining after mortality by predation and parasitism of early instars.

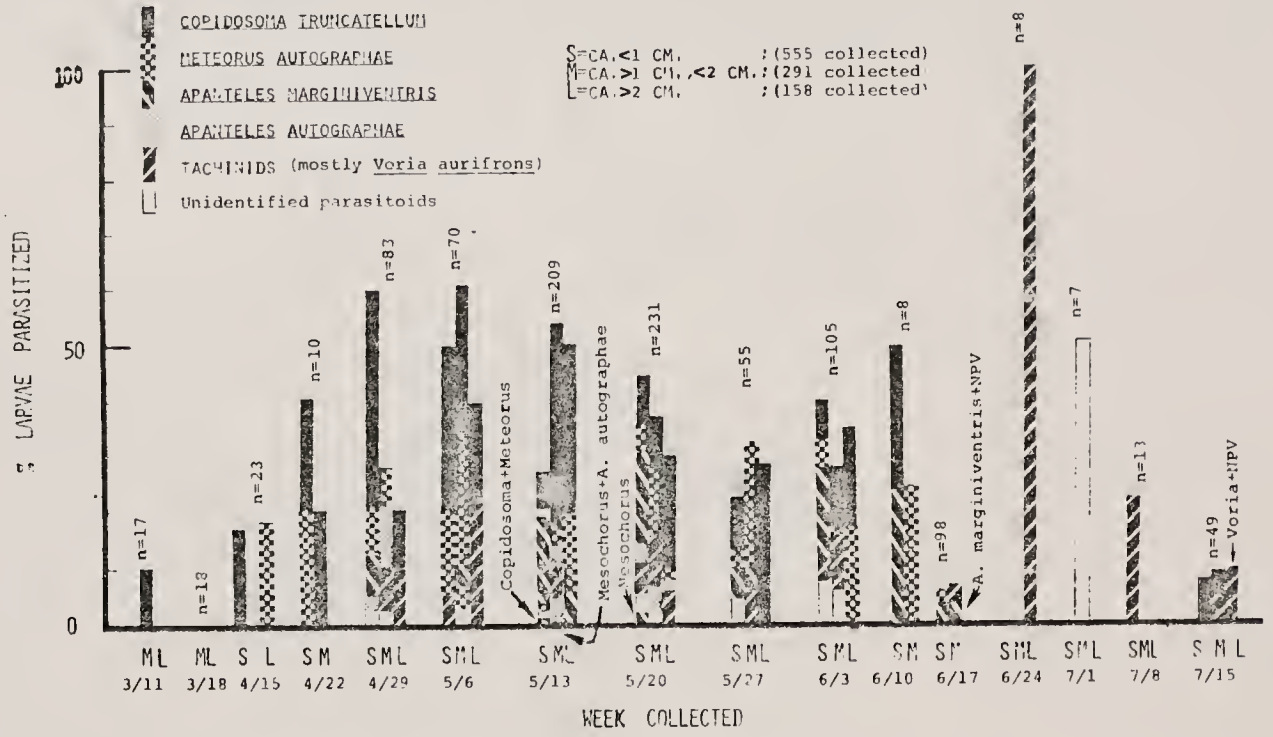

Fig. 9.--Parasitoids of the cabbage looper reared from larvae collected when small (S), medium (M), and large (L); larvae were collected in 1973, from collards. "n" is the total number of larvae used for each date.

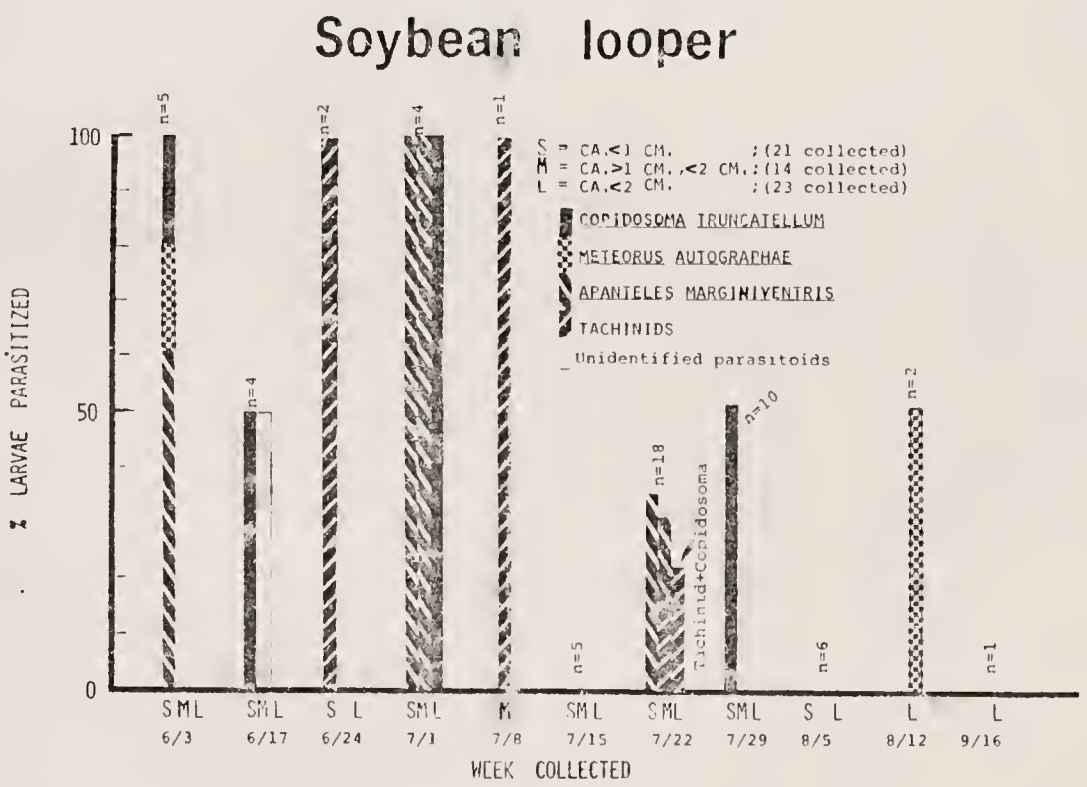

Fig. 10.--Parasitoids of the soybean looper reared from larvae collected when small (S), medium (M), and large (L); larvae were collected in 1973, from soybeans. "n" is the total number of larvae used on each date.

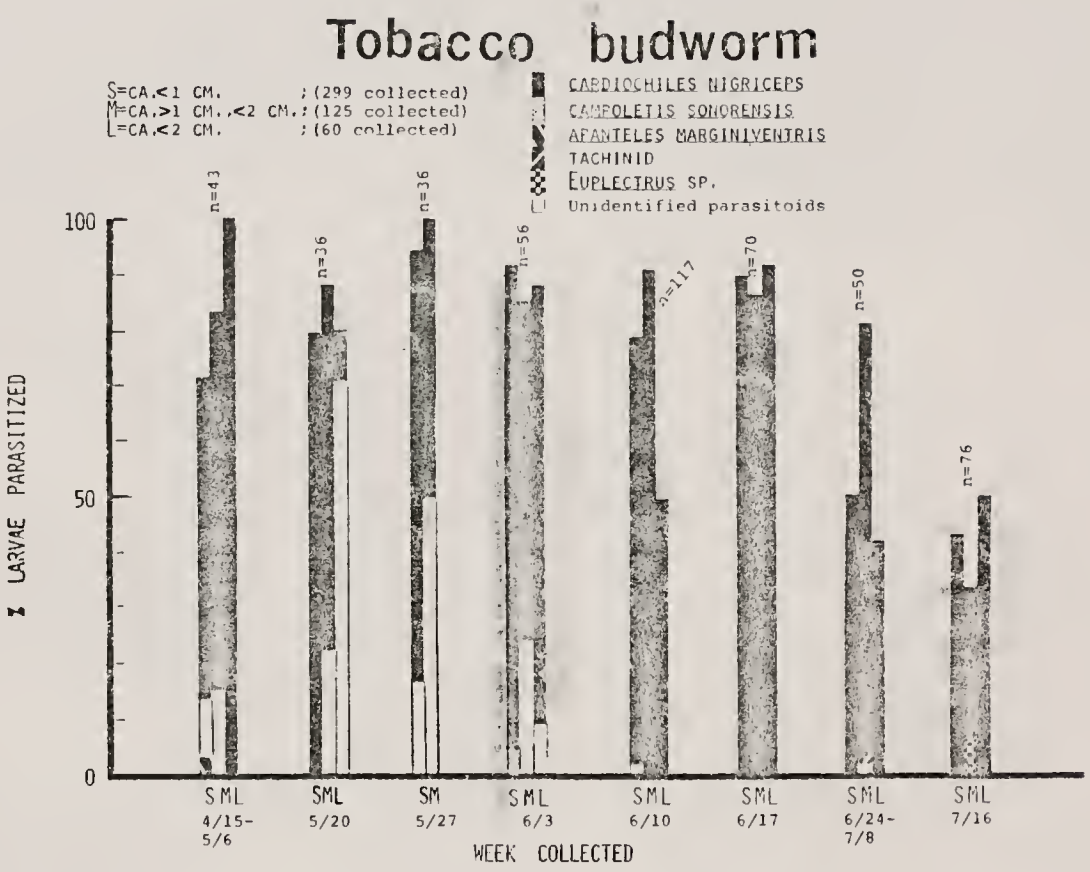

Fig. 11.--Parasitoids of the tobacco budworm reared from larvae collected when small (S), medium (M), and large (L); larvae were collected in 1973, from flue-cured tobacco. Unidentified parasitoids were probably primarily Cardiochiles nigriceps. "n" is the total number of larvae used on each date.

The sample size for soybean looper larvae was too small to reveal much about the selectivity of host size by its parasitoids (Fig. 10). However, Apanteles marginiventris was found most frequently from the small and medium category while tachinids, Copidosoma truncatellum and Meteorus autographae, were the only parasitoids recovered from larvae collected while large.

C. nigriceps dominated the parasitoid complex of the tobacco budworm so completely that it was the major parasitoid collected from small, medium, and large larvae (Fig. 11). However, some Campoletis sonorensis and A. marginiventris were recovered from larvae collected when they were small, and Euplectrus sp. and tachinids were recovered from larvae collected when they were medium-sized.

Parasitization of cabbage looper

Eggs.[1] Trichogramma spp. (primarily T. pretiosum (=Trichogramma semifumatum?), T. fasciatum, and T. perkinsi) were the only egg parasitoids of cabbage looper in the 8-acre system. Telenomus sp. was recovered from 1 Plusiinae egg (probably cabbage looper collected in the 1-acre shade).

Cabbage looper eggs in collards were parasitized from April through October in 1972 and from April until termination of the test in August in 1973 (Fig. 12a). Parasitization rates were generally above 10%, and were as high as 42% in September of 1972 and 55% during July 1973.

Parasitization of eggs in the spring on cabbage generally occurred later and rates were lower than on the earlier planted collards. Trends of

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[1]Eggs of Plusiinae or Heliothis spp. were not identified to species, but are generally labeled as being the major species identified in the larval stage from a particular crop, as described in Section I.

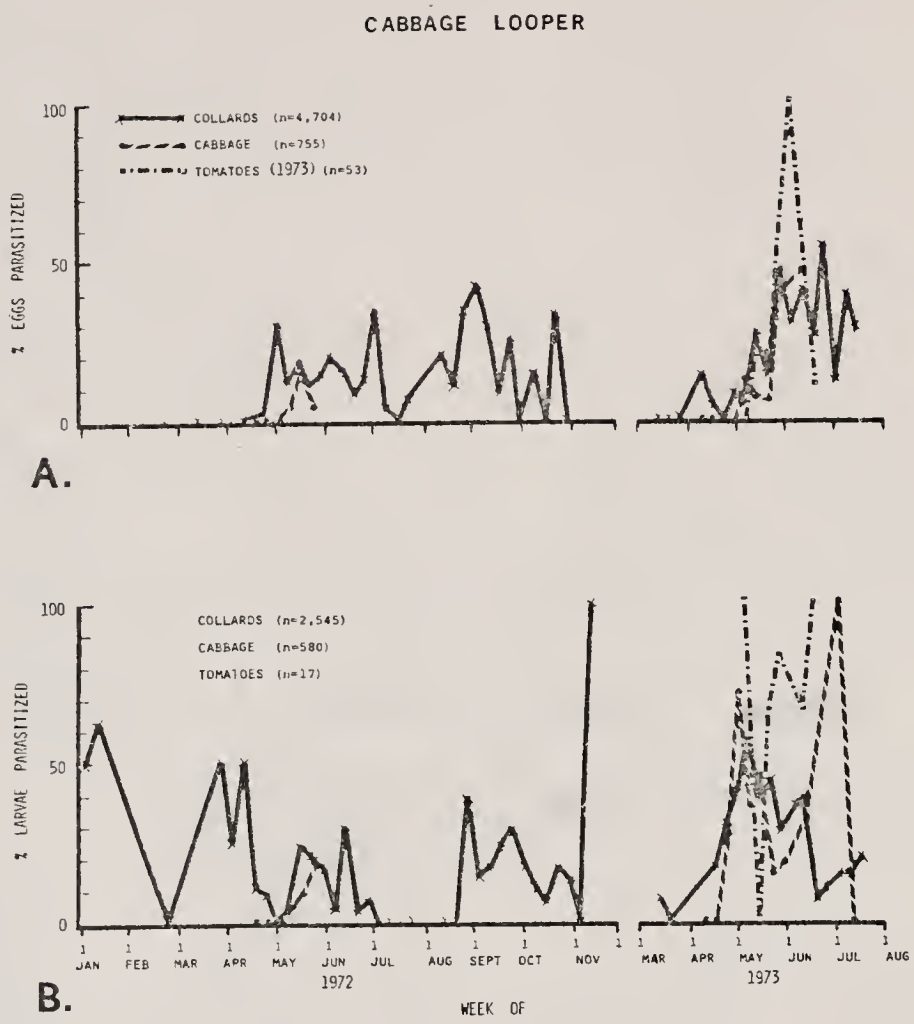

Fig. 12.--Seasonal parasitization of Plusiinae eggs and larvae, primarily cabbage looper, in collards, cabbage, and tomatoes in an 8-acre cropping system. "n" is the total number of eggs or larvae used for each crop. Parasitization of Plusiinae eggs and larvae collected from tomatoes in 1972 is presented in Fig. 13 since all Plusiinae identified from tomatoes during 1972 were soybean looper.

parasitization were similar, however, in tomatoes only a few Plusiinae eggs (probably cabbage looper) were collected in the spring of 1973 from tomatoes and most were parasitized. In fact, during 1 week (June 3, 1973) all eggs collected were parasitized. Three Plusiinae eggs, probably cabbage loopers, were also collected in flue-cured tobacco in the spring of 1973, but none were parasitized.

Larvae. The most common parasitoid of larvae of the cabbage looper in crops of the 8-acre system was Copidosoma truncatellum (Table 11). There was little difference in the complex of parasitoids that attacked cabbage loopers in the various crops; however, Meteorus autographae was proportionately less numerous in collards and entirely absent from cabbage in 1972. In 1973, it was recovered from neither cabbage nor tomatoes. Also, the only parasitoid collected in flue-cured tobacco was Apanteles autographae.

In 1973, M. autographae, A. marginiventris, and A. autographae did parasitize a greater proportion of the young larvae present in the system than in 1972. This resulted in less parasitism by C. truncatellum, and was probably due to the buildup of M. autographae and A. marginiventris on green cloverworm in white clover during the winter months, and buildup of A. autographae on larvae of Rachiplusia ou on the same crop during the early spring. Also, parasitization rates of larvae and eggs of cabbage looper were higher in 1973 (Fig. 12). This suggests that the parasitoid group was becoming more complex over time in the absence of insecticidal control and in the presence of a sustained cropping system that included host larvae throughout most of the year.

In collards, parasitization of cabbage looper larvae collected in 1972 was often higher than that of eggs, but it was also erratic (Fig. 12). Although ca. 25-50 % of the larvae collected in late March and early April were parasitized, during the week of April 30 no parasitization was

Table 11.--Relative occurrence of parasitoids of larvae of Plusiinae, primarily cabbage looper, in various crops in an 8-acre cropping system.

Crops	Total no. of parasitized larvae found	% parasitized by: *Copidosoma truncatellum*	*Meteorus autographae*	*Apanteles marginiventris*	*Apanteles autographae*	*Euplectrus* sp(p)	Tachinidae, primarily *Voria ruralis*[a]	Unknown
					1972			
Collards[b]	133	74	4	4	-	-	9	9
Cabbage[c]	18	56	-	6	-	-	11	27
Subtotal	151	73	3	4	-	-	9	11
					1973			
Collards[b]	655	41	27	13	5	-	11	3
Cabbage[c]	79	53	-	14	18	-	10	5
Tomatoes[d]	11	54	-	18	9	9	9	-
Flue-cured tobacco[c]	1	-	-	-	100	-	-	-
Okra[e]	1	100	-	-	-	-	-	-
Subtotal	747	42	24	13	7	1	11	3
Total[f]	898	47	20	12	5	1	11	5

[a]Also *Eucelatoria rubentis* and *Lespesia archippivora*.

[b]Plusiinae collected primarily in spring, summer, and fall.

[c]Plusiinae collected in spring.

[d]Plusiinae collected in spring and summer.

[e]Plusiinae collected in summer.

[f]1972 and 1973.

observed (Fig. 12b). Also, after an outbreak of nuclear polyhedrosis virus (NPV) and re-planting of collards (Fig. 1), few parasitized larvae were found from mid-June to mid-August. In 1973, parasitization of cabbage looper larvae in collards remained at rates of 28-56% throughout May and never dipped to the low rates of 1972 (Fig. 12b). However, after NPV was well established in the cabbage looper population in June, rate of parasitism by parasitoids dropped to 6% and did not surpass 20% up to the time sampling was terminated in mid-July.

In the spring cabbage, parasitism approximately doubled weekly in 1972 until this crop was removed from the system. (Parasitism went from 0-19%.) (Fig. 12b.) In 1973, when an additional parasitoid (A. autographae) was found, parasitism reached rates of 71 and 100% but dipped to 15% during the week of May 20.

Parasitism of cabbage looper larvae in tomatoes in the spring of 1973 was generally high (Fig. 12b). Eleven of 17 larvae collected were parasitized. However, in flue-cured tobacco in the spring, only 1 of 5 collected larvae collected was parasitized (20%).

Parasitization of soybean looper

Few soybean looper eggs or larvae were collected in the 8-acre system. However, the data collected on parasitoids of these soybean loopers might help explain why they were not numerous.

Eggs. In 1972 a substantial number of the eggs of soybean looper collected in the cropping system were parasitized (Fig. 13a). Of 74 eggs collected in tomatoes, in the spring and summer, and soybeans, in the summer, 34% were parasitized. Parasitism of eggs was lower in the summer (Fig. 13a). During the summer of 1973, none of 18 eggs collected

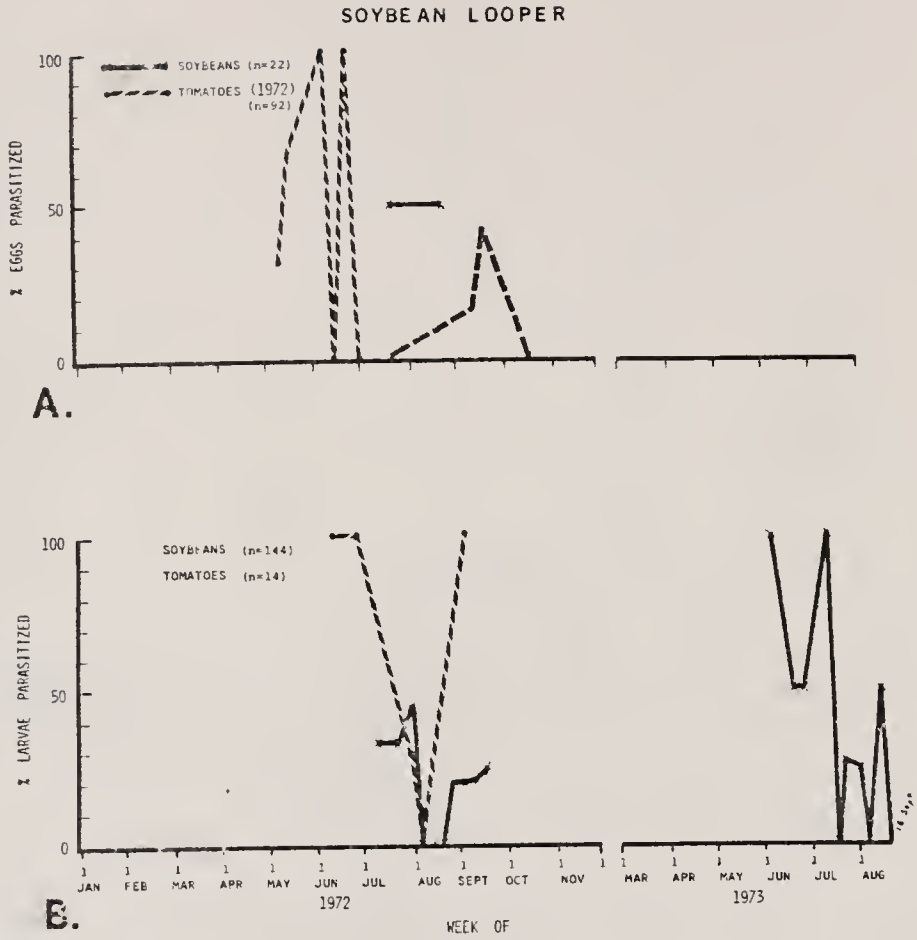

Fig. 13.--Seasonal parasitization of Plusiinae eggs and larvae, primarily soybean looper, in soybeans and tomatoes in an 8-acre cropping system. "n" is the total number of eggs or larvae used for each crop. No parasitized eggs of the soybean looper were found on soybeans in 1973. Also, parasitization of Plusiinae eggs and larvae collected from tomatoes in 1973 is presented in Fig. 10 since all Plusiinae identified from tomatoes during 1973 were cabbage looper.

on soybeans were parasitized. No Plusiinae eggs were collected in peanuts during the spring or summer of 1972.

Larvae. The larval parasitoids found most frequently from soybean loopers were C. truncatellum in 1972, and A. marginiventris in 1973 (Table 12). No A. autographae were found from soybean loopers, and tachinids were recovered from a higher percentage of soybean loopers than cabbage loopers.

Many soybean looper larvae collected in tomatoes in the spring and summer of 1972 were parasitized (Fig. 13b). But during the summer of that year in soybeans, where larger samples of the relatively dense population of soybean looper larvae were collected, parasitism rates were lower (0-33%) than in tomatoes (0-100%) (Fig. 13b). In peanuts in the summer of 1972, only 3 Plusiinae larvae were collected and 1 was parasitized (33%). In 1973, parasitization in soybeans ranged from 0-100%.

Parasitization of tobacco budworm

Eggs. Throughout the spring and summer, parasitism of tobacco budworm eggs in flue-cured and cigar-wrapper tobacco was virtually nil (Fig. 14a). Although a total of over 2500 eggs of Heliothis spp. were collected from these crops in the 8-acre system only 2 eggs were parasitized (<0.2%). (Also, after supplementary releases of over a million T. pretiosum in the 1-acre shade in 1972, only 2 of 67 eggs (<3.0%) of Heliothis spp. collected were found parasitized in cigar-wrapper tobacco (Section V).) This lack of parasitization by Trichogramma spp. in tobacco was also found by Rabb and Bradley (1968) and Gentry et al. (1973).

I collected too few eggs from wild hosts or white clover in the spring to estimate the parasitization of eggs of Heliothis spp. from these hosts in the spring. However, in tomatoes, parasitization of eggs of Heliothis

Table 12.--Relative occurrence of parasitoids of larvae of Plusiinae, primarily soybean looper, in various crops in an 8-acre cropping system.

Crop	Total no. of parasitized larvae found	% parasitized by				
		Copidosoma truncatellum	Meteorus autographae	Apanteles marginiventris	Tachinidae[a]	Unknown
				1972		
Soybeans[b]	23	52	5	17	26	-
Tomatoes[c]	5	100	-	-	-	-
Peanuts[c]	1	100	-	-	-	-
Subtotal	29	60	7	13	20	-
				1973		
Soybeans[c]	22	23	9	45	14	9
Bell peppers[c]	3	67	-	-	-	33
Subtotal	25	28	8	40	12	12
Total[d]	54	45	8	25	16	5

[a]Including Lespesia aletiae and Chaetophlepsis townsendi.

[b]Plusiinae collected primarily in late summer.

[c]Plusiinae collected in summer.

[d]1972 and 1973.

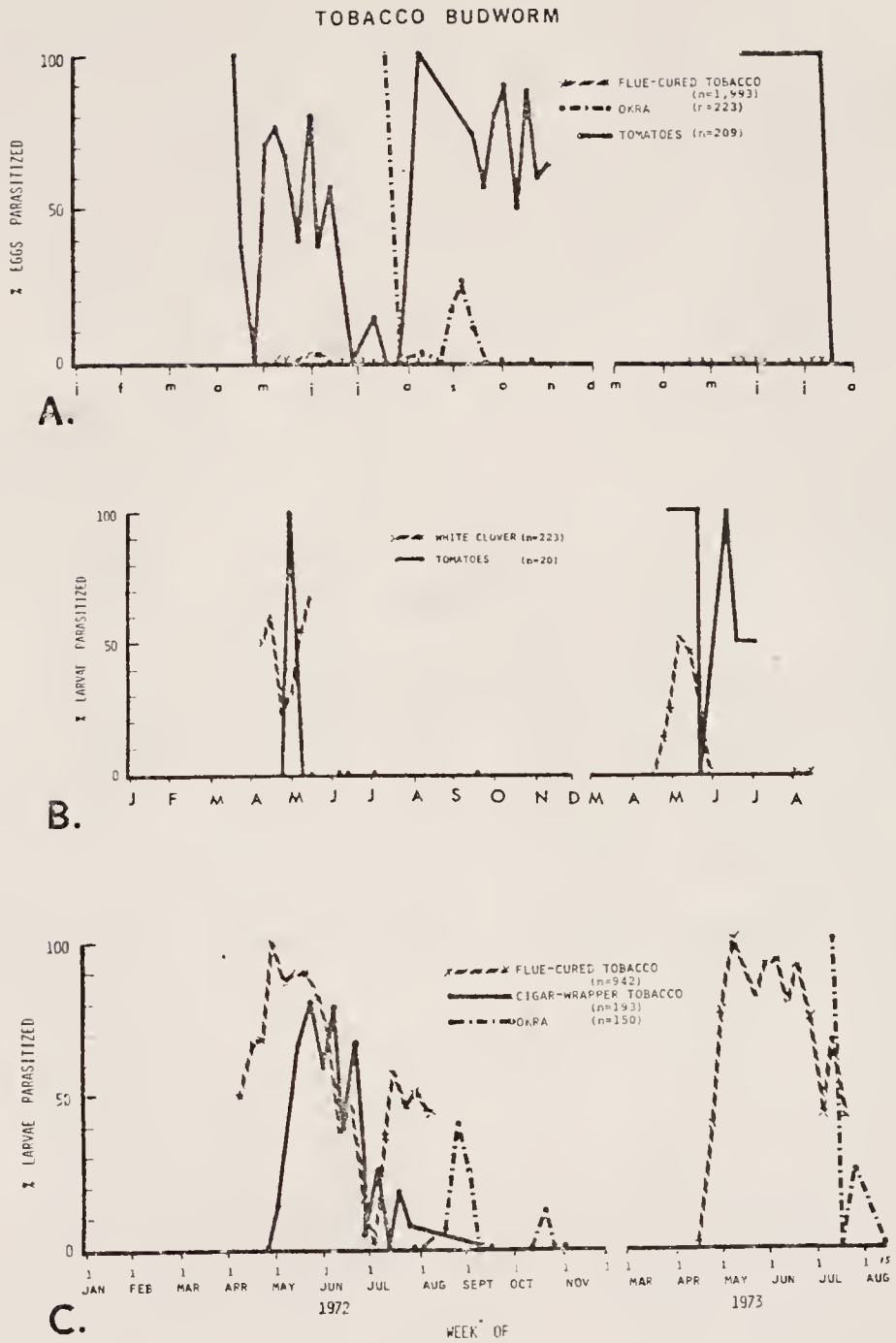

Fig. 14.--Seasonal parasitization of eggs and larvae of Heliothis spp. in flue-cured tobacco, cigar-wrapper tobacco, okra, tomatoes and white clover in an 8-acre cropping system; primarily tobacco budworm except in tomato and white clover. "n" is the total number of eggs or larvae used for each crop.

spp. was high (Fig. 14a) during the spring, and in other seasons. Parasitization was also substantial in okra during the summer months in 1972, but not in 1973.

In the fall, no Heliothis spp. eggs found on okra, an important host for the tobacco budworm in the 8-acre system, were parasitized by Trichogramma spp. Limited sampling on beggarweed and small flower morningglory, 2 other fall hosts of the tobacco budworm, indicated parasitism may be important in reducing overwintering numbers of tobacco budworms developing on these hosts.

Larvae. The most common parasitoid of tobacco budworm was C. nigriceps (Table 13). It was the primary parasitoid of tobacco budworm in tobacco, and most other crops and wild host plants attacked by larvae of the tobacco budworm. However, M. autographae was as common as C. nigriceps in larvae collected from white clover. Also, A. marginiventris and tachinids were relatively common parasitoids of the tobacco budworm found in white clover, okra, and tomatoes.

Parasitization of larvae in flue-cured tobacco and cigar-wrapper tobacco in 1972 was high from mid-April to mid-June and then declined to relatively low levels in late June and early July (Fig. 14c). Parasitization of larvae in flue-cured tobacco was higher in 1973 than in 1972, but it again dropped in late June. Similar trends occurred in parasitism of tobacco budworm eggs (Fig. 14a), and this was also similar to what I observed concerning parasitism of eggs and larvae of cabbage looper on collards (Fig. 12).

No factual explanation is offered for these declines, but it is likely that heavy insecticide treatment of a near-by patch of cigar-wrapper tobacco (Section I) may have had some effect on the parasitoids,

Table 13.--Relative occurrence of parasitoids of larvae of Heliothis spp., primarily tobacco budworm, in various crops in an 8-acre cropping system and in nearby wild hosts.

Crops	Total no. of parasitized larvae found	% parasitized by: Cardiochiles nigriceps	Meteorus autographae	Apanteles marginiventris	Netelia sp(p).	Prisomerus pacificus	Campoletis sonorensis	Euplectrus sp(p).	Tachinidae[a]	Unknown[b]
						1972				
Flue-cured tobacco[c]	266	56	1	1	-	7	1	-	1	33
Cigar-wrapper tobacco[c]	54	81	4	2	4	-	-	-	-	9
Okra[d]	5	40	-	20	-	-	-	-	20	20
Tomatoes[e,f]	1	100	-	-	-	-	-	-	-	-
White clover[e,f]	40	32	32	10	-	2	-	-	10	12
Subtotal	366	57	5	2	1	5	1	-	2	27
						1973				
Flue-cured tobacco[c]	369	91	-	1	-	-	<1	<1	<1	8
Crimson clover[e,f]	9	11	-	-	-	-	-	-	-	89
Okra[d]	3	100	-	-	-	-	-	-	-	-
Tomatoes[c,e]	5	60	-	40	-	-	-	-	-	-
White clover[e,f]	37	27	38	8	-	-	-	-	11	16
Subtotal	423	83	3	1	-	-	<1	<1	1	10
Total	789	71	4	2	<1	2	<1	<1	2	19

[a] Including Archytas marmoratus, Eucelatoria rubentis, and Lespesia archippivora.
[b] Many of these were probably larvae of C. nigriceps which died before spinning their cocoons.
[c] Heliothis spp. collected primarily in spring and summer.
[d] Heliothis spp. collected primarily in late summer.
[e] A majority of the identified larvae were corn earworm, but a number were tobacco budworm.
[f] Heliothis spp. collected primarily in spring.
[g] 1972 and 1973.

especially Trichogramma spp. (Stinner et al. 1974b). Also, several of the C. nigriceps collected during early to mid-June went into dormancy; and suggest that dormancy may have been a cause for the decline observed for parasitization of larvae of tobacco budworm. (In addition, a high incidence of NPV in larvae of cabbage looper in June undoubtedly affected the degree of parasitization of that species.)

Parasitization of larvae of Heliothis spp. was mostly moderate in the spring in white clover (Fig. 14b). But during a limited period, parasitism was high in tomatoes in the spring of both 1972 and 1973 (Fig. 14b).

In late summer and fall of 1972 in okra (Fig. 14c), no parasitoids were reared from larvae of Heliothis spp. on okra until mid-August. In late August the rate of parasitism was estimated at 40% (Fig. 14c). Subsequently parasitism dropped and remained near 0% for the remainder of the season. Collections of tobacco budworms were made in okra over a shorter period of time in 1973 (July 8-August 19), but 10 of 13 larvae collected in okra in 1973 were parasitized. This again suggested that the system was becoming more favorable for the parasitoid complex as time progressed.

Alternate hosts

The most important alternate hosts for parasitoids of the cabbage looper, soybean looper, and tobacco budworms found in the 8-acre system were the velvetbean caterpillar, the green cloverworm, and other Plusiinae. In the fall of 1972, velvetbean caterpillar eggs were found to harbor numerous Trichogramma spp. (T. semifumatum, T. fasciatum, T. perkinsi, and possibly Trichogramma nubilalum Ertle (Sudha Nagarkatti personal

communication[2])). During the winter of 1972-73 A. marginiventris and M. autographae were abundant in green cloverworms. R. ou probably served as an important source of C. truncatellum, M. autographae, and A. autographae.

In those crops with a majority of corn earworms, A. marginiventris, and tachinids, especially Archytas marmoratus were the major parasitoids. However, parasitization of corn earworm larvae was so low, these alternate hosts and the crops possessing this lepidopterous pest, apparently had a minor effect on the parasitoid complex for tobacco budworm.

Cabbage looper parasitoids. The complex of parasitoids that attacked cabbage loopers also attacked other Plusiinae, including the soybean looper, R. ou, and Argyrogramma verucca (Table 10). In field peas, parasitism of eggs of A. verucca reached high levels (Fig. 15a). The parasitoids produced probably had no direct impact on parasitism of eggs of cabbage loopers during 1972, although A. verucca in field peas may have served to increase the number of overwintering Trichogramma spp. somewhat, and subsequently helped to increase parasitism of cabbage looper eggs in 1973.

None of 9 Plusiinae eggs collected in white clover in 1973 were parasitized. However, since few eggs of R. ou were collected in white or crimson clover, the amount of parasitism that occurred on eggs of R. ou is unknown.

In addition to parasitism of Plusiinae, the high rates of parasitism of velvetbean caterpillar eggs which occurred late in the fall of 1972 in field peas and white clover, probably had a great impact on the cabbage looper since density of these parasitized eggs was much greater than that of any other lepidopterous species present in the 8-acre system during that period.

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[2]Letter dated 20 January 1975 from Sudha Nagarkatti, CIBC, Bangalore, India.

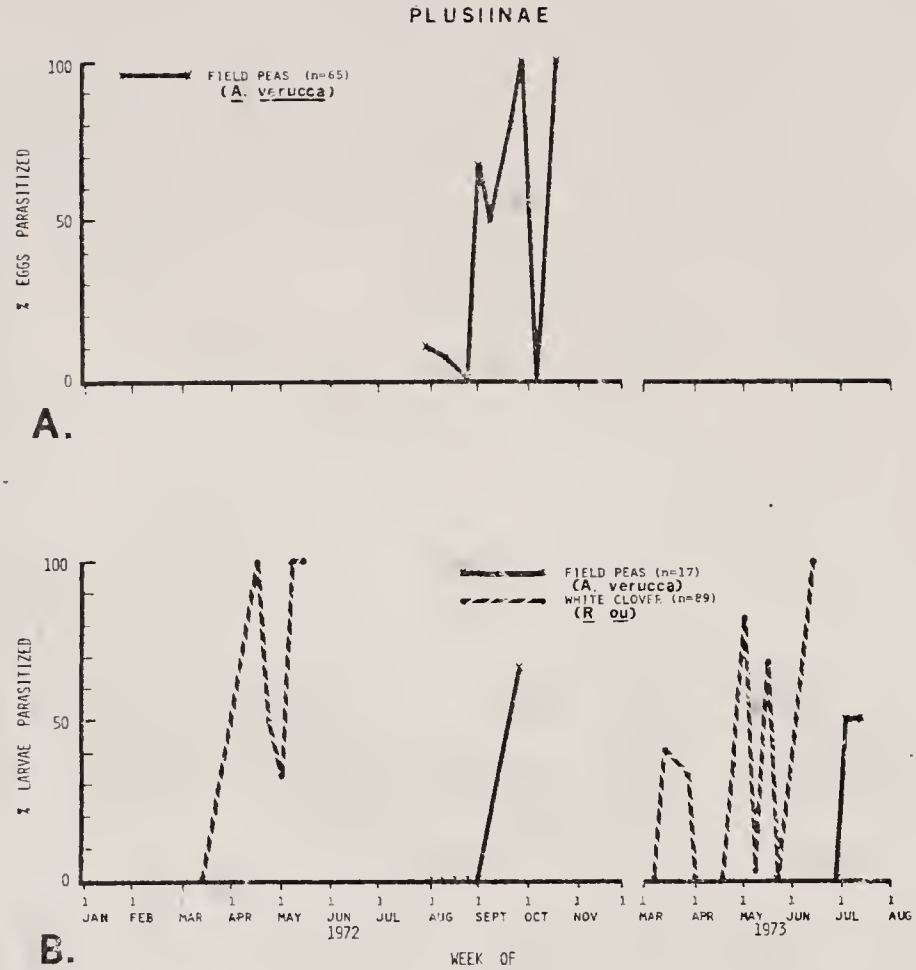

Fig. 15.--Seasonal parasitization of eggs and larvae of Plusiinae other than cabbage and soybean looper in white clover and field peas in an 8-acre cropping system. No parasitized eggs of Argyrogramma verucca were found on field peas in 1973. "n" is the total number of eggs or larvae used for each crop..

Relatively few larvae of the Plusiinae, A. verucca, collected in field peas of the cropping system were parasitized (Fig. 15b); therefore, parasitoids produced on this host species probably had little effect on the parasitoid complex of the cabbage looper. But in the spring of both 1972 and 1973 substantial numbers of larvae of another Plusiinae species, R. ou, were parasitized in white clover of the 8-acre system (Fig. 15b) and in crimson clover near the system in 1973. Many of these surely moved into collards and cabbage after the decline of R. ou populations. The major difference in the parasitoid complex attacking R. ou and A. verucca (Table 14), and that attacking cabbage loopers (Table 11), was that M. autographae seemed to be a more common parasitoid in 1972 on these alternate Plusiinae than it was on cabbage looper.

Soybean looper parasitoids. The complex of parasitoids collected from soybean loopers (Table 12) was similar to that collected from the cabbage looper (Table 11) and other Plusiinae (Table 14). The major differences seemed to be that Apanteles marginiventris and the tachinids were more important as parasitoids of the soybean looper than they were for other Plusiinae. Since parasitoids produced by the soybean looper were so few in number and were produced during peak production of parasitoids from the cabbage, they probably had little impact on the cabbage looper. However, parasitoids produced from cabbage loopers in crucifers may have affected soybean looper populations in the 8-acre system.

Tobacco budworm parasitoids. Since C. nigriceps is the major parasitoid of tobacco budworms and it is generally specific to tobacco budworms (Lewis et al. 1967), the role of alternate hosts for this parasitoid was probably not important. Corn earworm might be an important alternate host of other tobacco budworm larval parasitoids during some periods and in some

Table 14.--Relative occurrence of parasitoids of larvae of Plusiinae other than cabbage and soybean looper in various crops in an 8-acre cropping system and in nearby wild hosts.

Crops	Total no. of parasitized larvae found	% parasitized by						
		Copidosoma truncatellum	*Meteorus autographae*	*Apanteles marginiventris*	*Apanteles autographae*	*Euplectrus* sp(p).	Tachinids[a]	Unknown
					1972			
White clover[b]	14	26	57	7	-	-	-	-
Field peas[c]	2	-	50	50	-	-	-	-
Okra[d]	1	100	-	-	-	-	-	-
Wild hosts[e,f]	4	0	0	0	-	-	50	50
Subtotal	21	29	43	10	-	-	10	8
					1973			
White clover[b]	40	45	25	5	8	-	15	2
Crimson clover[b]	7	14	-	86	-	-	-	-
Field peas[c]	2	-	50	50	-	-	-	-
Peanuts[c]	1	-	-	-	-	-	-	100
Desmodium tortuosum[e]	1	-	-	-	-	100	-	-
Subtotal	51	37	22	18	6	2	12	3
Total[g]	72	35	28	15	4	1	11	6

[a]Including *Eucelatoria rubentis* and *Lespesia aletiae*.
[b]Most hosts were *Rachiplusia ou* collected in spring.
[c]Most hosts were *Argyrogramma verucca* collected in late summer.
[d]Plusiinae collected in late summer.
[e]Plusiinae collected in summer.
[f]These Plusiinae were collected by general sweeping of an area of volunteer growth and the host plant is unknown.
[g]1972 and 1973.

crops. However, the major larval parasitoids recovered from corn earworms were A. marginiventris and tachinids, including Archytas marmoratus, E. rubentis, and L. archippivora (Tables 10 and 15). With the possible exception of A. marginiventris, none of these species were important parasitoids of tobacco budworms. In addition to this, parasitism of larvae of Heliothis spp. in crops possessing mostly corn earworms was rarely found in 1972 or 1973 (Fig. 16b). Therefore it appears that corn earworm larvae were not important alternate hosts of the tobacco budworm parasitoids in this study.

Parasitism of eggs was substantial in squash, bush beans, bell peppers, and grain sorghum, and in sweet corn and field corn prior to silking (Fig. 16a). No eggs of Heliothis spp. were found to be parasitized in soybeans or millet. The Trichogramma spp. produced on corn earworms could have affected tobacco budworm egg populations in okra and tomatoes but not in the major host of tobacco budworms -- tobacco.

Host-habitat

Some trends of the influence of host-habitat on the parasitism by the parasitoids of the cabbage looper, soybean looper, and tobacco budworm were indicated. In particular, the highly effective parasitism of tobacco budworm larvae by C. nigriceps in tobacco is probably illustrative of effective host-habitat selection by this parasitoid. Similarly, Trichogramma spp. were highly effective in parasitizing eggs of both Plusiinae and Heliothis spp. in tomatoes (Fig. 12a, 13a, and 14a). Of 345 noctuid eggs collected in tomatoes well over 50% were parasitized.

Conversely, there was a negative effect of tobacco on parasitism by Trichogramma spp. Of over 2500 noctuid eggs collected in tobacco <0.2% were parasitized.

Rate of parasitism of eggs by Trichogramma spp. were high to moderate

Table 15.--Relative occurrence of parasitoids of larvae of Heliothis spp., primarily corn earworm, in various crops in an 8-acre cropping system in nearby wild hosts.

Crop[a]	Total no. of parasitized larvae found	% parasitized by		
		Apanteles marginiventris	Tachinids[b]	Unknown
		1972		
Sweet corn	2	-	50	50
Grain sorghum	3	33	33	33
Collards	1	-	100	-
Wild hosts[c]	1	-	100	-
Subtotal	7	14	57	29
		1973		
Field corn	1	-	100	-
Soybeans	2	50	-	50
Wild hosts[c]	2	50	-	50
Subtotal	5	40	20	40
Total	12	25	42	33

[a] Heliothis spp. collected primarily in the summer.

[b] Including Archytas marmoratus, Eucelatoria rubentis, and Lespesia archippivora.

[c] These Heliothis spp. were collected by general sweeping of an area of volunteer growth and the host plant(s) is(are) unknown.

[d] 1972 and 1973.

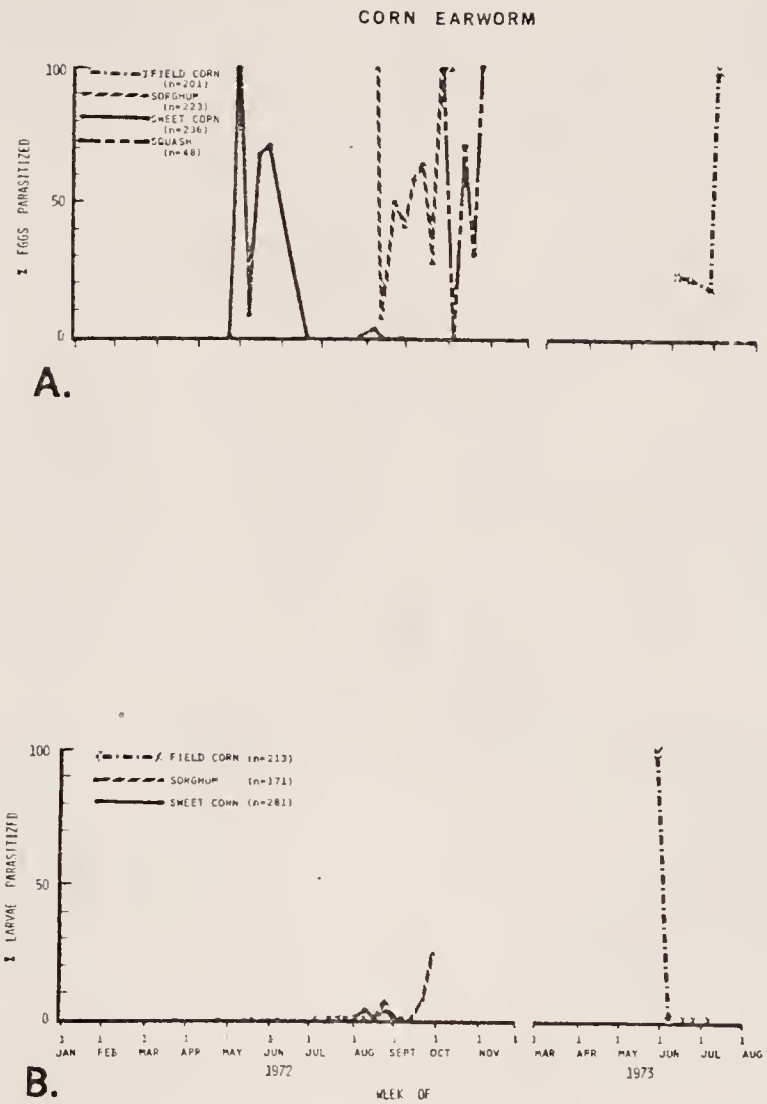

Fig. 16.--Seasonal parasitization of eggs and larvae of corn earworm in field corn, sweet corn, sorghum, and squash in an 8-acre cropping system. "n" is the total number of eggs or larvae used for each crop.

in other crops such as sorghum, squash, and field peas, and in field corn and sweet corn when eggs were collected mostly from the stem and leaves rather than the silks. In the remainder of the crops, parasitism of eggs by Trichogramma spp.was generally lower but substantial. Therefore, it seems that in some cases the host-habitat may be very critical in determining rate of parasitism of eggs of Plusiinae or Heliothis spp.

In contrast to mortality caused by egg parasitoids, mortality caused by the total complex of larvae parasitoids monitored was much more uniform among the crop components of the system, particularly among crops possessing Plusiinae larvae. Flue-cured tobacco, a crop in which egg parasitism was practically nil, did have high rates of larval parasitism. Also parasitism of larvae of Heliothis spp. and Plusiinae was usually high to moderate in tomatoes and white clover. However, parasitism of larvae was generally low in field corn, and other crops in which the major host species was corn earworms.

Some differences that occurred in the parasitoid complex of the various crop components in the 8-acre system was due primarily to lepidopterous pest preferences for various plants, as well as seasonal changes of preferred crops, and host specificity of some parasitoids. For example, C. nigriceps will oviposit in Heliothis spp., but immatures of C. nigriceps can not survive in corn earworms because of the encapsulating defense mechanism of this noctuid. Thus tobacco budworm was probably the only suitable host in the system for this parasitoid. Since tobacco budworms prefer tobacco, and corn earworms prefer corn and sorghum (Section II), parasitism was high in tobacco relative to that in corn or sorghum. C. nigriceps was apparently effective in parasitizing tobacco budworm and the complex of generally euryphagous parasitoid species which attack corn

earworm were not as effective. Perhaps the numerous and diverse complex of predaceous arthropods in corn and sorghum, which will be discussed in the next section, prevented parasitoids from developing to substantial densities in these crops. However, the influence of the characteristics of the crop plants themselves also were surely a key factor in regulating parasitism at low levels on crops such as corn and sorghum.

Pathogens

Cabbage looper

The major pathogen of cabbage looper in the 8-acre cropping system was nuclear polyhedrosis virus (NPV). Of 200 diseased larvae checked in 1972, 97.5% appeared to be infected with NPV and 2.5% with the fungi, Nomuraea spp. In 1973, 97.1% of the diseased larvae were apparently diseased with NPV, 2.2% with Nomuraea spp. and <1% with Bacillus spp.

However, few diseased cabbage looper larvae were found in collards and cabbage until they had reached high densities in July of 1972 and late May of 1973 (Table 16). Thereafter the incidence of disease generally remained at over 30% until late fall.

In a few cases a parasitoid (usually a tachinid) emerged from a cabbage looper that was noticeably diseased with NPV. However, this was rare; badly diseased cabbage looper larvae generally produced no parasitoids.

Soybean looper

Incidence of disease was generally low for soybean loopers (Table 16). However, after Nomuraea-diseased velvetbean caterpillar larvae reached high densities in soybeans in late August and September, several soybean looper larvae diseased with Nomuraea sp. were found in soybeans. In addition a few soybean looper larvae were infected with NPV.

Table 16.--Incidence of diseased larvae of Plusiinae in crops in an 8-acre cropping system.

Date (Week of)	Collards[a]		Cabbage[a]		Soybeans[a]		Tomatoes[c]		White clover[d]	
	No. larvae collected	% larvae diseased	No. larvae collected	% larvae diseased	No. larvae collected	% larvae diseased	No. larvae collected	% larvae diseased	No. larvae collected	% larvae diseased
1972										
Jan. 2	2	0	-	-	-	-	-	-	-	-
9	19	5	-	-	-	-	-	-	-	-
23	5	0	-	-	-	-	-	-	-	-
Mar. 5	-	-	-	-	-	-	-	-	1	0
26	12	0	-	-	-	-	-	-	-	-
Apr. 2	8	0	-	-	-	-	-	-	-	-
9	2	0	-	-	-	-	-	-	-	-
16	37	0	1	0	-	-	-	-	5	0
23	25	0	15	0	-	-	-	-	6	10
30	2	0	11	0	-	-	-	-	3	0
May 7	32	0	131	0	-	-	-	-	1	0
14	67	5	65	0	-	-	-	-	1	0
21	55	2	26	0	-	-	-	-	-	-
28	30	2	-	-	-	-	-	-	-	-
Jun. 4	74	0	-	-	-	-	-	-	-	-
11	17	0	-	-	-	-	1	0	-	-
18	35	0	-	-	1	0	-	-	-	-
25	67	18	-	-	2	0	-	-	1	0
Jul. 2	32	100	-	-	-	-	-	-	-	-
9	3	100	-	-	-	-	-	-	-	-
16	4	100	-	-	-	-	-	-	-	-
23	13	30	-	-	2	0	-	-	-	-
30	-	-	-	-	16	0	-	-	-	-
Aug. 6	-	-	-	-	1	0	-	-	-	-
13	13	8	-	-	2	0	-	-	-	-
20	14	24	-	-	1	0	-	-	-	-
27	13	31	-	-	5	20	-	-	-	-
Sep. 3	55	20	-	-	8	0	-	-	-	-
10	63	43	-	-	24	21	-	-	1	0
17	32	41	-	-	4	0	-	-	-	-
24	21	48	-	-	-	-	-	-	-	-
Oct. 1	46	63	-	-	-	-	-	-	-	-
8	44	68	-	-	-	-	-	-	-	-
15	16	63	-	-	-	-	-	-	-	-
22	6	50	-	-	-	-	-	-	-	-
29	23	52	-	-	-	-	-	-	-	-
Nov. 5	1	0	-	-	-	-	-	-	-	-
12	1	100	-	-	-	-	-	-	-	-
1973										
Mar. 4	-	-	-	-	-	-	-	-	1	0
11	15	0	-	-	-	-	-	-	5	20
18	18	0	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	6	17
Apr. 1	-	-	-	-	-	-	-	-	1	100
15	24	4	-	-	-	-	-	-	1	0
22	10	0	27	0	-	-	-	-	14	0
29	83	10	71	0	-	-	-	-	22	4
May 6	71	7	36	0	-	-	1	0	14	71
13	872	15	43	4	-	-	3	0	6	0
20	231	12	144	5	-	-	3	0	1	0
27	56	52	74	11	-	-	6	0	-	-
Jun. 3	106	53	-	-	5	0	-	-	-	-
10	8	50	-	-	-	-	3	33	1	0
17	88	60	-	-	4	0	1	0	-	-
24	9	78	-	-	2	0	-	-	-	-
Jul. 1	7	43	-	-	6	0	-	-	-	-
8	13	38	-	-	1	0	-	-	-	-
15	49	5	-	-	5	20	-	-	-	-
22	-	-	-	-	19	0	-	-	-	-
29	-	-	-	-	8	12	-	-	-	-
Aug. 5	-	-	-	-	6	17	-	-	-	-
12	-	-	-	-	2	0	-	-	-	-
Sep. 16	-	-	-	-	1	100	-	-	-	-

Note: Seven which were probably cabbage looper were collected in flue-cured tobacco and 2 (28%) were diseased. Eight which were probably soybean looper were collected in peanuts and bell peppers and none were diseased. Twenty-five which were probably Argyrogramma verucca were collected in field peas, peanuts, and okra, and none were diseased.

[a] Primarily cabbage looper.

[b] Primarily soybean looper.

[c] All identified in 1972 were soybean looper; all identified in 1973 were cabbage looper.

[d] Primarily Rachiplusia ou.

Tobacco budworm

In flue-cured tobacco, incidence of disease among tobacco budworms was substantial after population numbers reached high densities (Table 17). Of 8 diseased larvae sent to D. Hostetter and C. M. Ignoffo (Agr. Res. Serv., USDA, Columbia, MO), 4 were diseased with NPV and 4 with cyloplasmic virus. Most of the diseased larvae collected in flue-cured tobacco appeared to be infected by a virus.

Few tobacco budworm larvae collected in cigar-wrapper tobacco appeared to be diseased (Table 17). In white clover, a crop in which a substantial percentage of larvae of Heliothis spp. seemed to be diseased, 2 were diagnosed to be diseased by Bacillus spp. and 7 collected in 1972 were diseased with Nomuraea spp. Infection of collected larvae ranged from 0-45% in 1972 and 0-50% in 1973. Few diseased larvae of Heliothis spp. were collected in okra and tomatoes.

Alternate hosts

Plusiinae other than cabbage looper, did not reach high densities in the 8-acre cropping system and were usually not mortally affected by disease organisms (Table 16). Also, few diseased larvae of Heliothis spp. were collected in the crops possessing primarily corn earworms (Table 18). Thus soybean loopers, R. ou, A. verucca, and corn earworms were probably not important in increasing the concentration of disease agents in the cropping system.

Velvetbean caterpillars, which reached high densities, were, however, surely largely responsible for spreading Nomuraea spp. among soybean looper and other lepidopterous larvae in soybeans. Besides soybean loopers and velvetbean caterpillars in soybeans, some green cloverworms

Table 17.--Incidence of diseased larvae of Heliothis spp., primarily tobacco budworm, in crops in an 8-acre cropping system.

Date (Week of)	Flue-cured tobacco		Cigar-wrapper tobacco		White clover[a]		Tomato[a]		Okra	
	No. larvae collected	% larvae diseased	No. larvae collected	% larvae diseased	No. larvae collected	% larvae diseased	No. larvae collected	% larvae diseased	No. larvae collected	% larvae diseased
1972										
Apr. 9	8	0	-	-	2	0	-	-	-	-
16	21	10	-	-	10	10	-	-	-	-
23	22	9	7	0	79	11	2	0	-	-
30	13	0	-	-	20	45	1	0	-	-
May 7	31	10	-	-	11	27	1	0	-	-
14	39	5	3	0	3	0	1	0	-	-
21	29	3	5	0	-	-	-	-	-	-
28	33	3	15	0	-	-	-	-	-	-
Jun. 4	13	8	14	0	-	-	1	0	-	-
11	29	0	33	0	-	-	1	0	-	-
18	13	31	9	22	-	-	-	-	-	-
25	37	40	24	0	-	-	-	-	-	-
Jul. 2	9	11	4	0	-	-	1	0	-	-
9	11	9	11	0	-	-	-	-	-	-
16	28	4	11	0	-	-	-	-	-	-
23	45	13	55	9	1	0	-	-	5	0
30	36	19	-	-	-	-	-	-	16	6
Aug. 6	27	22	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	16	6
20	-	-	-	-	-	-	-	-	5	0
27	-	-	-	-	-	-	-	-	4	0
Sep. 3	-	-	-	-	-	-	-	-	8	0
10	-	-	2	0	-	-	-	-	1	0
17	-	-	-	-	-	-	3	33	-	-
Oct. 1	-	-	-	-	-	-	-	-	61	3
8	-	-	-	-	-	-	-	-	12	0
15	-	-	-	-	-	-	-	-	8	0
22	-	-	-	-	-	-	-	-	2	0
29	-	-	-	-	-	-	-	-	1	0
Nov. 5	-	-	-	-	1	0	-	-	2	0
1973										
Apr. 15	3	0	-	-	1	0	-	-	-	-
22	10	0	-	-	8	0	-	-	-	-
29	13	15	-	-	21	14	1	0	-	-
May 6	18	0	25	24	-	-	-	-	-	-
13	-	-	-	-	39	23	1	0	-	-
20	38	8	-	-	-	-	2	0	-	-
27	36	0	-	-	1	0	-	-	-	-
Jun. 3	54	2	-	-	-	-	-	-	-	-
10	117	3	-	-	-	-	1	0	-	-
17	70	0	-	-	-	-	2	50	-	-
24	27	11	-	-	-	-	-	-	-	-
Jul. 1	21	33	-	-	-	-	2	0	-	-
8	6	33	-	-	-	-	-	-	-	-
15	76	14	-	-	-	-	-	-	1	0
22	-	-	-	-	-	-	-	-	8	12
29	-	-	-	-	2	50	-	-	-	-
Aug. 12	-	-	-	-	1	0	-	-	-	-
Sep. 16	-	-	-	-	-	-	-	-	3	0

[a]Primarily corn earworm, but a number were tobacco budworms.

Table 18.--Incidence of diseased larvae of Heliothis spp., primarily corn earworm, in crops in an 8-acre cropping system.

Date (Week of)	Field corn		Sweet corn		Grain sorghum		Millet		Soybeans		Other crops[a]	
	No. larvae collected	% larvae diseased	No. larvae collected	% larvae diseased	No. larvae collected	% larvae diseased	No. larvae collected	% larvae diseased	No. larvae collected	% larvae diseased	No. larvae collected	% larvae diseased
1972												
Apr. 23	-	-	1	0	-	-	-	-	-	-	-	-
May 7	-	-	9	0	-	-	-	-	-	-	-	-
14	-	-	5	20	-	-	-	-	-	-	-	-
21	-	-	23	0	-	-	-	-	-	-	-	-
28	-	-	31	0	-	-	-	-	-	-	-	-
Jun. 4	-	-	8	0	-	-	-	-	-	-	-	-
11	-	-	27	0	-	-	-	-	-	-	-	-
18	-	-	1	0	-	-	-	-	-	-	-	-
25	-	-	5	0	-	-	-	-	-	-	-	-
Jul. 2	-	-	4	0	-	-	-	-	-	-	-	-
9	38	0	5	0	-	-	-	-	-	-	-	-
16	11	0	28	0	-	-	-	-	-	-	-	-
23	8	0	17	0	-	-	-	-	-	-	-	-
30	44	0	8	0	-	-	1	0	5	20	1	0
Aug. 6	16	31	29	7	34	9	-	-	-	-	-	-
13	-	-	37	3	54	11	-	-	-	-	-	-
20	-	-	30	10	31	16	-	-	-	-	-	-
27	-	-	12	8	23	4	16	31	2	0	2	0
Sep. 3	-	-	-	-	11	0	1	0	-	-	1	0
10	-	-	-	-	1	0	1	0	-	-	-	-
17	-	-	-	-	-	-	1	0	1	0	-	-
24	-	-	-	-	12	7	-	-	-	-	1	0
Oct. 1	-	-	-	-	7	0	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-	4	0
1973												
May 27	1	0	-	-	-	-	-	-	1	0	-	-
Jun. 3	1	0	-	-	-	-	-	-	1	0	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-
17	50	0	-	-	-	-	-	-	-	-	-	-
24	29	10	-	-	-	-	-	-	-	-	-	-
Jul. 1	-	-	-	-	-	-	-	-	-	-	-	-
8	15	13	-	-	-	-	-	-	1	0	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-	-	-	-
Aug. 5	-	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-

[a]Including bell peppers, collards, peanuts, squash, bush beans, pumpkins, and field peas.

in soybeans were also diseased with Nomuraea spp. In addition Metarrhizium anisopliae and Beauveria bassiana, 2 pathogens previously reported from diseased cabbage loopers (Thomas and Poinar 1973; Creighton 1973) were probably the causal organisms for death in some other green cloverworms collected in this crop (Ignoffo personal communication[3]).

Summary

The major parasitoid of at least 11 collected from cabbage loopers, was Copidosoma truncatellum. Six parasitoids were reared from soybean looper with each about equally common. By far the predominant parasitoid of tobacco budworms was Cardiochiles nigriceps.

Meteorus autographae, Apanteles marginiventris, Copidosoma truncatellum, and Voria ruralis were collected during all seasons and Trichogramma spp. were collected during much of the year. Eucelatoria rubentis, Lespesia archippivora, Apanteles autographae, Cardiochiles nigriceps, and Archytas marmoratus were found from April to October. Other species were found during an even more restricted period.

The host stage(s) utilized by the various parasitoids varied from the egg stage which was utilized primarily by Trichogramma spp. to the small-larvae category which was utilized by A. marginiventris, Campoletis sonorensis, and other parasitoids, to the egg stage and all of the larval instars utilized by C. truncatellum. A variety of parasitoids utilized the various larval stages of cabbage looper, whereas the various larval stages of tobacco budworm were mostly utilized by C. nigriceps.

---

[3]Letter dated 3 April 1973 from C. M. Ignoffo, Agr. Res. Serv., USDA, Columbia, MO.

Parasitization of cabbage looper eggs in collards and cabbage was generally above 10% and was estimated as high as 55% in cabbage in 1973. Most cabbage looper eggs collected in the spring tomatoes were parasitized. Parasitization of larvae in collards was generally higher butmore erratic than egg parasitism. Parasitization of cabbage looper larvae reached highest levels in tomatoes and cabbage in the spring. Parasitization of larvae and eggs of cabbage looper was higher in 1973 than in 1972 and the parasitoid complex appeared to be becoming more complex in the 8-acre cropping system.

Relatively few soybean looper eggs or larvae were collected in any crops. However, a substantial percentage of eggs were parasitized in soybeans and tomatoes in 1972 but not in 1973. Parasitization of larvae was generally high in tomatoes and soybeans.

Parasitization of tobacco budworm eggs in tobacco was virtually non-existant, while it was high in tomatoes and substantial during some periods in okra. However, parasitism of tobacco budworm larvae in tobacco was generally at high levels and often over 80%. High rates of parasitism also occurred in tomatoes during the spring and lower levels generally occurred in okra and white clover. There was a marked decline in parasitization of tobacco budworm larvae and eggs (and cabbage looper larvae and eggs) in late June and early July which may have been caused by insecticide drift from nearby cigar-wrapper tobacco shades, estivating parasitoids, and high incidence of NPV (in cabbage looper) or a combination of these factors.

The most important alternate hosts for parasitoids of the cabbage looper, soybean looper and tobacco budworm were probably the velvetbean caterpillar, the green cloverworm, Rachiplusia ou, and Argyrogramma

verucca in that order. Corn earworms served infrequently as an alternate host of these parasitoids.

The host-habitat probably influenced greatly the amount of parasitism occurring upon a host in several instances. Tobacco was particularly well-suited to C. nigriceps and tomatoes was a favorable "host-habitat" for various Trichogramma spp.

Pathogens, particularly nuclear polyhedrosis virus, caused much mortality of cabbage looper after it reached high densities in late May or July. They did not mortally affect a significant number of soybean loopers, or tobacco budworms, although several were found affecting these pests, including Nomuraea sp..

SECTION IV

PREDACEOUS ARTHROPODS

Predaceous arthropods are generally not as specific as parasitoids or pathogens in selecting hosts (Sweetman 1936; Clausen 1962; Doutt 1964; van den Bosch and Messenger 1973), but may be more important as a group than other entomophages in regulating many potential pests at noneconomic levels. Epizootics caused by pathogens are quite important in suppressing population densities of pests, but seem to be associated with high concentrations of host populations (Huffaker 1971). However, according to Huffaker (1971), "there are so many circumstances other than high host density that must be met concommitantly for some epizootics to occur that we cannot view pathogens generally as a very reliable regulator of population size." And van den Bosch and Messenger (1973) stated that:

> . . . although predators have been far overshadowed by parasites in classical biological control, they nevertheless have been of great significance in several programs, . . . and their importance in naturally occurring biological control is inestimable. For example in cotton in California's San Joaquin Valley, predators are much more widely important in restraining the major lepidopterous pests (i.e., bollworm, cabbage looper, beet armyworm) than are parasites. The world-wide eruption of spider mites in the wake of widespread use of chemical insecticide has mainly resulted from the elimination of predators of spider mites by insecticides (McMurtry et al. 1970; Huffaker et al. 1970).

Species composition and seasonal occurrence of predaceous arthropod complexes related to the cabbage looper, soybean looper, or tobacco budworm, have been determined by numerous researchers on various crops

(Sutherland 1966; Oatman and Platner 1969; Hasse 1971; Turnipseed 1972; Neal 1974; Whitcomb 1974), but most studies have taken place in cotton fields (Whitcomb and Bell 1964; van den Bosch and Hagen 1966; Lingren et al. 1968ab; Falcon et al. 1968; Dinkins et al. 1970ab; Ridgway and Lingren 1972; Shepard et al. 1972; Ehler et al. 1973; Ehler and van den Bosch 1974). Most field studies of predaceous arthropods have involved a single crop. However, Whitcomb and Bell (1964), Lincoln et al. (1967), and Whitcomb (1974) dealt with systems of crops. Also, extensive studies have been conducted in the Brazos Valley of Texas on the natural populations of predaceous arthropods in a cropping system involving ca. 9 mi^2 (Coppedge et al. 1971).

In the 8-acre cropping system, predaceous arthropods preyed on numerous soybean loopers, cabbage loopers, and tobacco budworms, and were undoubtedly a primary factor contributing to the reduction of populations densities that regularly occurred in the stages from egg to large larval (Section II). This section covers the predator component of the arthropod complex associated with the 3 target pests within the 8-acre system of crops. First, I established the occurrences and major sources of various predaceous arthropods in the system; then I attempted to determine the degree to which these predaceous arthropods might act as effective suppressants on population densities of the cabbage looper, soybean looper, and tobacco budworm.

Literature Review

Commonly, numerous predaceous arthropods have been found in various cropping systems (Whitcomb and Bell 1964; van den Bosch and Hagen 1966; Whitcomb 1974). Whitcomb (1974) reported over 600 predaceous arthropod

species from Arkansas cotton fields (Whitcomb and Bell 1964) and he and his colleagues have found over 1,000 species of predators in soybean fields (Whitcomb 1974).

Hemipterous predators are among the most noticeable and perhaps most effective consumers of many pests in various crops (Whitcomb and Bell 1964; van den Bosch and Hagen 1966). Lingren et al. (1968b) found Geocoris punctipes (Say), and to a lesser extent a damsel bug, Nabis alternatus Parshley, to be particularly effective in consuming eggs and larvae of Heliothis spp. in petri dishes and small cages. G. punctipes was "more consistently present than most other species in untreated cotton fields in Arkansas" (Whitcomb and Bell 1964), and Neal (1974) considered G. punctipes and Nabis spp. as possibly the major regulators of lepidopterous pests in soybeans. Whitcomb and Bell (1964) also found Nabis spp. to consume numerous eggs and larvae of lepidopterous species in cotton.

Another Hemiptera group, Orius spp., has been credited with being effective against the corn earworm in corn (Barber 1936) and cotton (Ewing and Ivy 1943; Whitcomb and Bell 1964). Also, according to van den Bosch and Hagen (1966), Orius spp. seem to be among the species least harmed by insecticide treatments of cotton. However, Lingren (personal communication[1]) found this anthocorid to be particularly susceptible to several insecticides. Neal (1974) reported that another anthocorid, Cardiastethus assimilis (Reuter), was occasionally common in soybean fields and found to feed on eggs of noctuids.

Numerous other predaceous Hemiptera have been reported to occur in various cropping systems (Hayslip et al. 1953; Whitcomb

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[1]P. D. Lingren, Cotton Insects Res. Laboratory, Agr. Res. Serv., USDA, College Station, TX.

and Bell 1964; Neal 1974; Whitcomb 1974). Podisus maculiventris (Say) has commonly been recognized as an important predator of various pests, and Neal (1974) suggested it may be particularly important in Florida soybeans. Whitcomb and Bell (1974) found P. maculiventris to be a valuable predator against large corn earworms. Jalysus spinosus (Say) has been considered to be an important predator of tobacco budworm eggs in tobacco (Elsey 1971, 1972); hence a considerable amount of research is currently being conducted on this species in hopes of manipulating it in tobacco pest management schemes (Elsey 1971, 1972, 1973; Elsey and Stinner 1971). Reduviids (Whitcomb and Bell 1964; van den Bosch and Hagen 1966; Neal 1974; Whitcomb 1974) and predaceous mirids (Whitcomb and Bell 1964; Neal 1974) are also oftentimes an important part of the predator complex of some cropping systems. Neal (1974) found a black fleahopper, Spanogonicus albofasciatus (Reuter) preyed on lepidopterous eggs and was most numerous in soybeans in June.

Although often seemingly scarce in crops (Whitcomb and Bell 1964; Neal 1974; Sutherland 1966), Chrysopa spp. are capable of consuming large numbers of lepidopterous eggs (Whitcomb and Bell 1964; Lingren et al. 1968b; Neal 1974). The Chrysopa carnea-group, which includes Chrysopa carnea Stephens, Chrysopa rufilabris Burmeister, and Chrysopa externa Hagen, are the most economically important group of chrysopids (Tauber 1974).

Another family of Neuroptera, the brown lacewings, or hemerobiids are also found frequently at low levels of abundance in many crops. Pimentel (1961a) and Neal (1974) observed several species of brown lacewings preying on eggs and larvae of several noctuids.

Coccinellids, or lady beetles, are one of the most notable groups

of predators in the history of biological control (DeBach 1974). They are often credited with being primarily aphid-feeders (van den Bosch and Hagen 1966; DeBach 1974). However, Whitcomb and Bell (1964) found that a number of species fed on eggs and small larvae of Lepidoptera. Coccinellids preyed on more corn earworm eggs placed in the field than any other group of predators (Whitcomb and Bell 1964). Coleomegilla maculata (De Geer) and Hippodamia convergens (Guerin-Meneville) are the coccinellid species most commonly reported as occurring in various cropping systems possessing large number of Plusiinae and Heliothis spp. (Hayslip et al. 1953; Whitcomb and Bell 1964; van den Bosch and Hagen 1966; Sutherland 1966; Hasse 1971; Neal 1974; Wieres and Chiang 1973).

Neal (1974) found that smaller species, including Scymnus spp., were the most common of the predaceous coccinellids in Florida soybean fields. Although these small coccinellids are probably most important as predators of aphids and mites, they will consume lepidopterous eggs (Lingren et al. 1968b; Neal 1974).

Many carabids, or ground beetles, are important predators, especially of large Lepidoptera larvae (Whitcomb and Bell 1964; van den Bosch and Hagen 1966). Calleida decora (F.) and Nemotarsus elegans Le Conte were the carabids most commonly found on soybean foliage in northern Florida (Neal 1974). In Neal's (1974) study, lepidopterous larvae were the favored food of C. decora, but N. elegans fed about equally on both eggs and small larvae (Neal 1974).

Another group of Coleoptera, the genus Notoxus, is common in many cropping systems (van den Bosch and Hagen 1966; Hasse 1971; Neal 1974), particularly in areas in which soils are sandy (van den Bosch and Hagen

1966; Neal 1974). Neal (1974) did find Notoxus monodon monodon (F.) and Notoxus calcaratus Horn feeding on eggs and 1st-instar larvae of noctuids in the laboratory. Orphanides et al. (1971) found N. calcaratus were effective predators of eggs and 1st-instar larvae of the pink bollworm, Pectinophora gossypiella (Saunders).

There are a number of other groups of predaceous Coleoptera that are probably quite important as parts of the predator complexes present in many cropping systems (Whitcomb and Bell 1964; Hasse 1971; Neal 1973). For instance some members of the family Staphylinidae appear to be very important predators. However, according to Whitcomb (1974), research on this group has been almost paralyzed because of the complexity of the taxonomy.

According to Whitcomb (1974), earwigs (Dermaptera) are perhaps one of the most "under-rated" of the predaceous arthropod groups. Doru lineare (Escholz) which has been observed to feed on numerous lepidopterous eggs and larvae in the laboratory has been the subject of little research.

Another group which Whitcomb (1974) feels is of primary importance in our cropping systems are the ants (Formicidae). Although they may also be serious pests, Whitcomb (1974) states: "eliminate them from the soybean or sugarcane field and outbreaks of other serious pests tend to result." In their studies in Arkansas, Whitcomb and Bell (1964) found ants eliminated a major portion of the corn earworm eggs placed in cotton fields.

Spiders (Araneida) are abundant in most cropping systems (Whitcomb 1974) and all are predaceous (Whitcomb and Bell 1964). However, Whitcomb (1974) points out that spiders are general feeders and are not always beneficial since they feed on many beneficial entomophages. But they

also prey on many pest species and may serve as alternate hosts for certain predaceous arthropods that are more effective against lepidopterous pests when the "normal" prey of those predators are not abundant (Whitcomb 1974).

Many other predaceous arthropods are important in the predaceous complexes of various cropping systems. For instance, Odonata may be important predators of adult Lepidoptera in some cropping systems (Neal and Whitcomb 1972; Whitcomb 1974) and syrphids have been reported to feed on larvae of Lepidoptera (Pimentel 1961b). Whitcomb (1974) and Rabb (1971) have emphasized the importance of the diverse complex of predaceous arthropods within a cropping system in regulating pest species. However, because of the large number of species, wide variation in individual species populations and great diversity of behavior among species, an accurate assessment of the role of a particular predaceous arthropod complex is very difficult to determine. Still, indicator species can be identified and used to gain knowledge of the characteristics of the predaceous arthropod complexes and their role in suppressing pest species (Whitcomb 1974).

Predators of Cabbage Looper

Direct visual observations are necessary in order to determine with certainty what species are predaceous and the number of hosts consumed. Unfortunately, this tedious and time-consuming task has caused researchers to approach field studies on predation in an indirect manner. For instance, McKinney (1944) observed that large numbers of cabbage looper eggs on lettuce had been consumed by what he assumed to be arthropod predators. Also, Ru (personal communication[2]) observed large losses of cabbage looper eggs in cabbage fields that he attributed to predation. In cotton, DeLoach

[2]Nguyen Ru, University of Florida, Gainesville, FL.

and Peters (1972) indicated egg losses of 50-70% within 24 hr after cabbage looper eggs were placed on cotton plants in the field. Extrapolation of these data indicated that 69-70% of the eggs would have disappeared had they been left on the plant until hatch (ca. 72 hr). They attributed these losses to predators; and, the most abundant predators in their study were Orius insidiosus (Say), H. convergens, and C. maculata.

Another study in cotton fields by Falcon et al. (1968) showed that the cabbage looper became an economic pest when arthropod predators of cabbage looper eggs and small larvae were suppressed by certain insecticide spray programs. They indicated that Orius tristicolor (White), Geocoris pallens Stal, Collops vittatus (Say), Nabis americoferus Carayon, and Chrysopa carnea were the most important predators. In a similar study, but using an insecticide-check method and age-specific life tables, Ehler et al. (1973) and Ehler and van den Bosch (1974) found that these species, with the exception of C. vittatus, were the most important arthropod predators inflicting mortality on small larvae of cabbage looper in cotton. They concluded that predation of other life stages of the pest was of less importance.

In cruciferous crops in several areas of the United States, coccinellids appear to be among the most abundant of species likely to prey on cabbage looper. . . (Oatman and Platner 1969; Wieres and Chiang 1973.) Whitcomb and Bell (1964) found that coccinellids were important predators of cabbage looper eggs in Arkansas cotton. Although less abundant, chrysopids may in some cases affect the population levels of the cabbage looper. Other predators or predator groups such as Labidura riparia Pallas (Ru and Strandberg[3] personal communications); Eythemis simplicicollis

[3]Letter dated 13 November 1973 from J. O. Strandberg, Agr. Res. and Educ. Center, University of Florida, Sanford, FL.

(Say) (Whitcomb and Bell 1964); Polistis spp. (Poe personal communication[4]); Vespula spp. (Sutherland 1966); and spiders (Pimentel 1961a) are sometimes relatively abundant and important predators of cabbage looper in cabbage, collards, cotton, and tomatoes.

Sutherland (1966) accumulated some of the earliest seasonal records on predators associated with the cabbage looper. However, the limited data presented make it difficult to determine the seasonal occurrence of the spiders, coccinellids, chrysopids, nabids, and syrphids he counted. It appears that coccinellids and nabids occurred mostly during mid-summer, whereas the other predators occurred mostly throughout the season (June-October). In other studies on seasonal occurrence, Oatman and Platner (1969) generally found the predaceous arthropods they counted (coccinellids, Geocoris spp., Orius spp., and Chrysopa spp.) were most abundant during the early and late part of the year, with the lowest numbers found in the mid-summer months. In their counts of coccinellids, Neuroptera, and syrphids in Minnesota cabbage during July-September, Weires and Chiang (1973) found that numbers were low in July but increased substantially in August.

Obviously, many factors including the varied and complex nature of agro-ecosystems, lack of host specificity, and difficulty of direct observation have made it difficult for researchers to obtain estimates of the true value of natural control of cabbage looper by predators. However, at least 20 species or species complexes of predaceous arthropods have been reported feeding on various life stages of the cabbage looper in the field (Table 19). Some of these species and others have been observed consuming large numbers of cabbage looper eggs and young larvae in the laboratory (Table 20)

[4]Letter dated 26 October 1973 from S. L. Poe, Agr. Res. and Educ. Center, University of Florida, Brandenton, FL.

Table 19.--Arthropod predators observed feeding on cabbage looper in the field.

Host stage fed on	Predator	Researcher
Egg	Chrysopidae	
	Chrysopa spp.	Whitcomb and Bell (1964)
	Coccinellidae	
	Coleomegilla maculata (DeGeer)	Whitcomb and Bell (1964)
	Hippodamia convergens Guérin-Méneville	Whitcomb and Bell (1964)
	Coccinella novemnotata Herbst	Whitcomb and Bell (1964)
	Labiduridae	
	Labidura riparia Pallas	Ru (personal communication)[a]
Larva	Araneida	Pimentel (1961b)
	Carabidae	
	Calosoma peregrinator Guérin-Méneville	McKinney (1944)
	Coccinellidae	
	Coccinella transversoguttata richardsoni Brown	Pimentel (1961b)
	Coleomegilla maculata	Pimentel (1961b)
	Hippodamia convergens	Pimentel (1961b)
	Chrysopidae	
	Chrysopa spp.	Pimentel (1961b)
	Labiduridae	
	L. riparia	Strandberg and Tucker (personal communication)[b]
	Nabidae	
	Nabis americoferus Carayon	Sutherland (1966)
	Pentatomidae	
	Podisus maculiventris (Say)	Hayslip *et al.* (1953)
	Reduviidae	
	Zelus bilobus (Say)	Hayslip *et al.* (1953)
	Z. exsanguis (Stal)	Whitcomb and Bell (1964)
	Syrphidae	
	Sphaerophoria asymmetrica Knutson	Pimentel (1961b)
	S. contigua Macquart	Pimentel (1961b)
	S. philanthus (Meigen)	Pimentel (1961b)
	Toxomerus marginatus (Say)	Pimentel (1961b)
	Vespidae	
	Polistes spp.	Poe (personal communication)[c]
	Vespula spp.	Sutherland (1966)
Pupa[d]	*Calosoma sayi* Dejean	Whitcomb (personal communiation)[b]
	Formicidae	Elsey (1969)
	Labiduridae	
	L. riparia	Strandberg and Tucker (personal communication)[b]
Adult	Asilidae	
	Asilus sp.	Zeller (1869)
	Libellulidae	
	Erythemis simplicicollis (Say)	Whitcomb and Bell (1964)
	Lycosidae	
	Lycosa rabida Walck.	Whitcomb and Bell (1964)
	Oxyopidae	
	Peucetia viridans (Hentz)	Whitcomb and Bell (1964)
	Salticidae	
	Phidippus variegatus (Lucas)	Chittenden (1902)

[a]Nguyen Ru, Univ. of Florida, Gainesville, FL.

[b]J. O. Strandberg and Linda Tucker, Agricultural Research and Education Center, Univ. of Florida, Sanford, FL.

[c]S. L. Poe, Agricultural Research and Education Center, Univ. of Florida, Bradenton, FL.

[d]Elsey (1969) observed a harlequin bug, *Murgantia histrioniana* Hahn, puncturing a pupae which subsequently died.

[e]W. H. Whitcomb, Univ. of Florida, Gainesville, FL.

Table 20.--Arthropod predators observed feeding on immatures of the cabbage looper in the laboratory.

Host stage fed on	Predator	Stage and period of observation	No. cabbage loopers consumed	Reference
Egg	Chrysopidae			
	Chrysopa carnea Stephens	Complete larval[a]	311-332[b]	Sutherland (1965)
	C. oculata Say	Complete larval	272-323	Sutherland (1965)
	Coccinellidae			
	Coleomegilla maculata (DeGeer)	Complete larval	260	Sutherland (1965)
	Cycloneda munda (Say)	-	-	Sutherland (1965)
Egg + 1st-instar larvae	Chrysopidae			
	C. oculata	Complete larval	221+172[c]	Sutherland (1965)
	Syrphidae			
	Toxomerus marginatus (Say)	Complete larval (13 days)	63+112	Sutherland (1966)
1st-instar larvae + 2nd- and 3rd-instar larvae	Nabidae			
	Nabis americoferus Carayon	Adult (34 days)	406+187	Sutherland (1966)
2nd-instar larvae	Coccinellidae			
	C. maculata	Adult	-	Kerr[d]
	Cycloneda sanguinea (L.)	Adult	-	Kerr
	Forficulidae			
	Doru lineare (Eschscholtz)	-	-	Kerr
	Labiduridae			
	Euborellia annulipes (Lucas)	-	-	Kerr
	Labidura riparia (Pallas)	-	-	Kerr
	Lycosidae			
	Pardosa milvina (Hentz)	-	-	Kerr
	Schizocosa sp.	-	-	Kerr
	Pentatomidae			
	Alcaeorrhynchus grandis (Dallas)	-	-	Kerr
	(Phymatidae)	-	-	Kerr
	Pisauridae			
	Dapanus mirus (Walck.)	-	-	Kerr
	Salticidae			
	Metaphidippus sp.	-	-	Kerr
	(Staphylinidae)	-	-	Kerr
	Tettigoniidae			
	Conocephalus sp.	-	-	Kerr

[a]Egg to adult.

[b]Range.

[c]Number eggs consumed plus number 1st-instar larvae consumed.

[d]Observations made during a pest management class at Univ. of Florida, Gainesville, FL, taught by S. H. Kerr.

Predators of Soybean Loopers

Recently, Hasse (1971) and Neal (1974) attempted to identify the predators which occurred in soybean fields. These and subsequent studies have revealed over 1,000 predaceous arthropods in soybean fields of Florida (Whitcomb et al. 1972; Whitcomb 1974). Hasse (1971) reported that Nabis spp. and G. punctipes were the most common and that Notoxus spp. and C. maculata were relatively common. Neal (1974) found Nabis spp., G. punctipes, several ground beetles, L. riparia, and possibly Solenopsis invicta Buren were the most important predators.

In studies in other areas, Barry (1973) reported on the species composition of the predaceous arthropod fauna in Missouri soybeans. Tugwell et al. (1972) reported on the seasonal abundance of G. punctipes, Lebia analis Dejean, and O. insidiosus in Arkansas soybean fields. Turnipseed (1972) found that nabids, Geocoris spp., and spiders were the 3 most abundant predators groups in South Carolina soybean fields, and Shepard et al. (1974b) reported on the seasonal abundance of these groups in that region.

Shepard et al. found Nabis spp. to be the most abundant predator. Numbers were highest in September and early October of 1972 and August and early September of 1973. Although spiders were less numerous than Nabis spp., they peaked during similar periods. Trend of seasonal abundance for Geocoris spp. was similar, but densities of this group were generally lower than those of either Nabis spp. or spiders. In order of decreasing abundance, other predators found were larvae of predaceous coccinellids, larvae of Chrysopa spp., adults of C. maculata, and adults of Orius spp. Shepard et al. summed up their study stating: "in general all predatory species were more abundant in

late August and September when populations of pest species (Lepidoptera) were highest (Carner et al. 1974)".

Similar trends in predaceous arthropod seasonal abundance in soybean fields were observed by Neal (1974). He found numbers of G. punctipes ranged from 1,453 to 8,231 per acre from August to mid-October in untreated fields at Quincy, FL. Nabis spp. were more numerous than G. punctipes during these months (3,380-18,157 per acre); however, near Gainesville, FL, Neal found G. punctipes reached levels of 24,210/acre during the late season. O. insidiosus and C. maculata were common but less abundant than Geocoris spp. and Nabis spp. P. maculiventris, C. decora, Notoxus spp. and D. lineare were generally at low densities, but sometimes reached relatively high numbers in September and October. Spiders were present in low numbers and Neal reported that they were probably of little value in regulating pest insects on soybeans in northern Florida.

Relatively few reports of predaceous arthropods feeding on soybean looper has been recorded in the literature (Table 21). However, many of the predators recorded to feed on eggs and larvae of other Lepidoptera are likely to be important predators of soybean looper and further studies will undoubtedly demonstrate this.

Predators of Tobacco Budworm

Entomological work conducted in cotton has resulted in considerable research on predaceous arthropods associated with Heliothis spp., including the tobacco budworm. Ridgway and Lingren (1972) reviewed many of these works and summarized information on the common predators known to attack Heliothis spp. Their summary covers distribution, abundance, and levels of control. The major predaceous arthropods known to attack Heliothis spp.,

Table 21.--Arthropod predators observed feeding on soybean loopers in the laboratory or field.

Host stage fed on	Predator	Researcher
Eggs	Gryllidae	
	Gryllus spp.	Neal (1974)
	Formicidae	
	Solenopsis invicta (Buren)[a]	Neal (1974)
	Labiduridae	
	Euborellia annulipes (Lucas)	
	Miridae	
	Spanogonicus albofasciatus (Reuter)	Neal *et al.* (1972)
Larvae	Coccinellidae	
	Coleomegilla maculata (DeGeer)	Hasse (1971)
	Formicidae	
	Camponotus socius (Roger)[a]	Whitcomb *et al.* (1972)
	S. invicta[a]	Whitcomb *et al.* (1972)
	Pentatomidae	
	Stirethus anchorago (F.) (if starved)	Waddill and Shepard (1964)
	Reduviidae	
	Sinea diaclema (F.)	Neal (1974)
	Vespidae	
	Polistes exclamans Viereck[a]	Neal (1974)
	P. metricus Say[a]	Neal (1974)
	P. rubiginosus Lepeletier[a]	Neal (1974)
Early instars	Carabidae	
	Calleida decora (F.)	Neal (1974)
	Dolichopodids[a]	Neal (1974)
	Lygaeidae	
	Geocoris spp.[a]	Neal (1974)
Late instars	Pentatomidae	
	Podisus maculiventris (Say)	Neal (1974)
Adults	Libellulidae	
	Erythemis simplicicollis (Say)[a]	Neal & Whitcomb (1972)

[a]Observed in the field. All other observations were made in the laboratory.

including tobacco budworms, are generally the same ones reported for cabbage locpers and soybean loopers; however, a number of additional predators have also been reported feeding on Heliothis spp. (Whitcomb and Bell 1964). Concerning this high number of predaceous arthropods associated with Heliothis spp., Ridgway and Lingren (1972) stated that "although many beneficial arthropods are probably involved in the regulation of Heliothis populations, the most important predators are probably limited to 10 to 15 families . . . ."

The fact that Heliothis spp. are in some cases insecticide-induced pests that often become economically damaging only after suppression of predaceous arthropods has been documented by Lingren et al. (1968a), Doutt and Smith (1971), van den Bosch et al. (1971), and Steenwyk et al. (1975). However, Heliothis spp. have been reported inflicting heavy damage to crops such as cotton well before the advent of major inorganic insecticide usage (Quaintance and Bishopp 1905).

Prior to Whitcomb and Bell's 1964 publication, little had been published on the importance of predaceous arthropods as regulators of Heliothis spp. populations. Whitcomb and Bell not only identified many of the predaceous species commonly found in cotton fields, but also noted consumption of eggs and larvae of Heliothis spp. in the field, and gave some indication of the relative importance of different predator groups. In addition they reported on seasonal occurrence of some of the predaceous species and commented on the role of associated crops and wild host plants. Van den Bosch and Hagen (1966) also listed some of the important predators of Heliothis spp. in California cotton. Later Lingren et al. (1968b) showed the potential of some arthropods for preying on tobacco budworm (and corn earworm) eggs and larvae in cotton. Lopez (1973) continued with more extensive studies on consumption of Heliothis spp. by certain predaceous arthropods.

In seasonal abundance studies, Whitcomb and Bell (1964) found that both sucking predators (Geocoris spp., Nabis spp., Orius spp., Chrysopa spp., and assassin bugs, or reduviids), and chewing predators (coccinellids, Collops spp., Lebia sp., and predaceous mites) increased more than 2-fold in July and August over early season numbers in cotton. Abundance of sucking predators increased more rapidly and they reached higher densities than chewing predators. In other cotton fields, from June through September, Whitcomb and Bell (1964) found that coccinellids as a group were the most abundant of the predators sampled, but Geocoris spp. and Orius spp. were also quite numerous.

In other studies on seasonal abundance of predaceous arthropods, Dinkins et al. (1970ab) found that Geocoris spp., Nabis spp., Coleomegilla maculata, Scymnus spp., and Chrysopa carnea were most abundant early in the season in June and early July in Mississippi cotton. Chrysopa rufilabris was most abundant later in the season. From samples made in June and July in Texas cotton, Shepard et al. (1972) found predaceous arthropods, including Orius spp., C. maculata, H. convergens, Scymnus spp., and spiders, to be most abundant in July.

In the Rio Grande Valley of Texas, Schuster and Boling (1974) found, from samples taken from April through May, that most predaceous species were generally most abundant in May. However, coccinellids were most abundant in April during 1 of 3 years of sampling.

A majority of the studies on seasonal abundance of predaceous arthropods associated with the tobacco budworm have been conducted on cotton. But in the southeastern United States, the tobacco budworm is an important pest of tobacco. Despite this fact, little work has been undertaken to investigate the predator complex associated with tobacco

(Elsey 1972). Elsey (1972) suggested "predation would appear to be the most important factor contributing to egg mortality on tobacco since Rabb and Bradley (1968) suggested little loss from egg parasitism."

Thomas (1945) did report that the suckfly, Cyrtopeltis varians (Distant), preyed on eggs and 1st-instar larvae of Heliothis spp. in tobacco. Lawson (1959) found a number of predators feeding on tobacco hornworm eggs and larvae, including Chrysopa rufilabris, J. spinosus, and Peucetia viridens (Hartz), which might also prey on tobacco budworms in tobacco. Neunzig (1969) observed G. punctipes, Polistes spp., and Peucetia sp. feeding on tobacco budworm larvae in tobacco, and observed Pselliopus cinctus (F.), and several other predators, feeding on corn earworms in tobacco and other crops.

Although little work has been done on the abundance of predators in tobacco, Elsey (1972) did conduct a survey of predaceous arthropods on tobacco, similar to but more limited than that of Whitcomb and Bell's (1964) on cotton. The research was, however, concerned primarily with a stilt bug, J. spinosus. Elsey (1972) found J. spinosus were more numerous than other predators and that G. punctipes, Oecanthus spp., and coccinellids followed as most commonly collected species of predators in that order. He recorded 68 instances of stilt bugs suspected of preying on eggs of tobacco budworm and only 1 instance of another predator (C. varians) feeding on eggs of tobacco budworms.

In surveys from early June to late August, Elsey (1972) found those predator groups which were most numerous (J. spinosus, G. punctipes, and Oecanthus spp.) reached maximum numbers in late July or early August, and were found infrequently in early June. Spiders were generally uniformly present throughout the season.

Whitcomb and Bell (1964) reported on the relationships of other crops to the predator complex occurring in cotton. Alfalfa, white clover, and small grains all were good sources of predators, and when these crops were cut in mid-summer, numbers of predaceous arthropods increased substantially in cotton, suggesting movement into this crop. Corn was another excellent source of predators; however, Whitcomb and Bell (1964) reported that this crop may "draw the predators from cotton." Whitcomb and Bell (1964) reported that crimson clover, vetch, johnsongrass, sudan, sorghum, lespedeza, and soybeans are good predator sources. Also, weeds such as dock, Rumex sp., careless weeds, Amaranthus spp., Coreopsis spp., smartweeds, Polygonum spp., and fleabanes, Erigeron spp. are good predator sources. They reported that bermuda pastures and forested areas were not promising predator sources for cotton fields.

Methods and Materials

Counts were made of adults and immatures of Geocoris spp. (lygaeid bugs), Nabis spp. (damsel bugs), Orius insidiosus (Say) (minute pirate bugs), Chrysopa spp. (green lacewings), and large predaceous coccinellids, adults of small coccinellids, adults and immatures of ground beetles, earwigs and spiders, and other predaceous arthropods including adults and immatures of Podisus maculiventris (Say) (spined soldier bug), Jalysus spinosus (Say) (stilt bug), assassin bugs, and Micromus spp. (brown lacewings), and adults of Notoxus spp. (ant-like flower beetles). Counts made in the field and obtained by means of whole plant inspections, plant shakes, and sweeps in the 8-acre cropping system were discussed in Section I.

In addition, counts of the predaceous arthropod groups mentioned

in the previous paragraph, plus ants, were made and reported from the D-vac samples discussed in Section I. D-vac samples were stored in 70% ethanol until they could be sorted and counted under a stereo-microscope.

Numerous predaceous arthropod groups were collected in D-vac samples. Most Neuroptera were sent to C. Tauber, Cornell Univ., Ithaca, NY; most true bugs were sent to F. W. Mead, Div. Plant Industry, Gainesville, FL, and most small lady beetles were sent to R. E. Waites, Univ. of Florida, Gainesville, FL.

The predaceous arthropods groups selected for counting were those 1) frequently mentioned in the literature as major predators of the cabbage looper, soybean looper, and/or the tobacco budworm, 2) good indicator species for the predaceous arthropod complex associated with these 3 noctuids, and/or 3) relatively common in the 8-acre system.

In this section D-vac samples and sweeps were used primarily to establish the species composition of the predaceous arthropod complex, whereas whole plant inspections and plant shakes were primarily used to establish seasonal occurrences and abundances of the predaceous arthropods and to relate the predaceous arthropods populations to the pest populations. However, when necessary, data from certain sampling techniques are used to supplement or replace data from other sampling techniques. Also some of the data from whole plant inspections and D-vac samples taken in the 1-acre shade (Section I) were used to supplement that from the 8-acre system.

Some data on seasonal occurrences and abundances of the cabbage looper, soybean looper, and tobacco budworm presented in Section II are repeated (though manipulated) in this section in order to more clearly

show positive and negative relationships of the predaceous arthropod complex and the 3 noctuids in the 8-acre system. Pertinent methods and materials were presented in Section I.

Results and Discussion

As indicated in the literature review, the arthropod complex preying upon the cabbage looper, soybean looper, tobacco budworm, and other pests, is very difficult and time-consuming to characterize and monitor. In the 8-acre cropping system and supporting experiments, I did not attempt to determine all of the "important" predators of the target pests since this was beyond the scope of my study. Instead, I attempted to find some predaceous arthropod groups that might be of major importance, and attempted to determine how these might be interrelated with the 3 pest species and crops within the 8-acre system.

In most crops, whole plant inspections appeared to sample the predaceous arthropod complex as well or better than D-vac samples. For instance, from June 4-July 16, 1972, more individuals of the selected predaceous arthropods counted, were estimated for flue-cured tobacco, white clover, and field corn from whole inspection sampling than from D-vac sampling (Table 22). Estimates from whole plant inspections and D-vac samples were similar in collards. However, one-half as many predaceous arthropods were estimated from whole plant inspections of soybeans as were estimated from D-vac samples.

Also, during July 9-August 23, 1972, in white clover, whole plant inspection estimates were higher for Geocoris and Nabis spp., large coccinellids, and spiders than estimates from D-vac samples (Table 23). However,

Table 22.--Comparison of total number of selected predaceous arthropods estimated from whole plant inspections and D-vac samples in 5 crops of the 8-acre cropping system from June 4 to July 16, 1972.

Date (Week of)	Number per acre (in 1000's) in representative crops									
	Collards		Soybeans		Flue-cured tobacco		White clover		Field corn	
	WPI	D-vac	WPI	D-vac	WPI	D-vac	WPI	D-vac	WPI	D-vac
Jun. 4	8.5	2.8	0.5	0.9	15.0	1.0	24.7	14.7	7.8	2.5
11	3.0	1.8	0.6	1.0	0.8	1.2	34.9	27.4	8.5	1.5
18	2.2[a]	-	3.3	4.7	3.5	1.7	-	18.7[a]	41.9	3.6
25	1.2	2.9	0.7	4.9	1.5	1.1	31.3	22.8	3.0	4.8
Jul. 2	1.2	1.0	2.5	3.2	1.3	1.4	-	58.9[a]	6.1	5.2
9	0.7	3.5	2.2	3.7	0.0	0.9	18.0	5.2	44.0	6.1
16	0.7	3.3	1.5	7.3	0.6	0.5	10.0	22.2	2.0	6.9
$\bar{x}$	2.5	2.5	1.4	3.7	3.2	1.1	23.8	18.5	16.2	4.4

Note: Numbers in the columns represent the following predators: adults and immatures of Geocoris spp. (mostly Geocoris punctipes), Nabis spp., Orius insidiosus, and Chrysopa spp. (mostly C. rufilabris); adults of Coleomegilla maculata and Hippodamia convergens; immatures of the large Coccinellidae; adults of the small Coccinellidae; adults and immatures of Carabidae and Dermaptera; other predaceous insects including adults and immatures of Podisus maculiventris, Jalysus spinosus, Reduviidae, and Hemerobiidae, and adults of Notoxus spp.; and adults and immatures of Araneida.

[a]Not used in the mean ($\bar{x}$).

Table 23.--Comparison of number of individuals in 5 predaceous arthropod groups estimated from whole plant inspections and D-vac samples in white clover from July 9 to August 27, 1972.

Date (Week of)	Numbers per acre (in 1000's) in representative groups									
	Geocoris spp. and *Nabis* spp.		*Orius* spp.		*Chrysopa* spp.		Large coccinellids		Spiders	
	WPI	D-vac	WPI	D-vac	WPI	D-vac	WPI	D-vac	WPI	D-vac
Jul. 9	0.7	2.7	0.0	0.4	0.0	0.1	17.3	0.7	4.0	1.1
16	1.7	10.0	0.0	0.7	0.0	0.0	6.0	3.8	2.0	6.7
23	6.0	22.4	0.0	0.9	0.0	0.0	22.7	7.7	10.7	0.0
30	12.0	10.5	0.0	0.1	0.0	<0.1	5.3	1.1	1.3	4.2
Aug. 6	18.0	3.3	0.0	0.1	0.0	0.0	38.6	0.2	11.3	1.1
13	31.3	8.2	0.0	0.6	0.0	0.0	9.3	0.9	10.7	7.8
20	34.7	2.1	0.0	0.6	0.0	0.0	22.7	0.8	18.0	4.7
27	6.0	0.4	0.7	0.4	0.0	0.0	3.3	0.1	12.0	2.3
$\bar{x}$	13.8	7.4	0.1	0.5	0.0	<0.1	15.7	1.9	8.8	3.5

[a]Not used in the mean ($\bar{x}$).

estimates were lower for adults and immatures of Orius spp. and Chrysopa spp. although estimates were low from both sampling techniques.

Experiments were not designed to determine whether whole plant inspection or D-vac sampling yielded the most precise and consistent index of actual absolute values for predator densities. However, it appeared there was not a great deal of difference between the 2 sampling techniques in this respect; and whole plant inspections were probably better for estimating absolute density values. Also, D-vac samples were not taken as often as whole plant inspection samples. Therefore, estimates from whole plant inspections are primarily used when discussing abundances of predaceous arthropods. However, D-vac samples were used as practically the sole means for collecting specimens for identification, and are used to supplement the abundance data from whole plant inspections.

The Predator Complex

The most abundant predator groups in the 8-acre system were Coleomegilla maculata, Geocoris punctipes, Hippodamia convergens, Nabis spp., and spiders (Table 24). G. punctipes, Nabis spp., and spiders were usually found at relatively high densities throughout the year, although very few immatures of G. punctipes or Nabis spp. were collected in the winter. In contrast, C. maculata were found infrequently in the 8-acre system in the fall and winter months and did not reach high density levels until sometime in April. Similarly the other predator groups that occurred at low densities were hardest to find in the winter (Table 24). One exception was brown lacewings which were most common in the spring and winter.

Table 24.-- Relative abundance of selected predaceous arthropods found in 8-acre cropping system; abundance in the 8-acre system is presented as monthly estimates of number per acre in 100's.

Month	1. Geocoris	2. Nabis	3. Orius	4. Chrysopa	5. Coleomegilla	6. Hippodamia	7. Lady beetle larvae	8. Scymnus	9. Ground beetles	10. Earwigs	11. Ants[a]	12. Other predators	13. Spiders
1971-72													
Dec.	<0.1	<0.1	0.0	<0.1	0.0	0.0	0.0	<0.1	0.0	0.0	<0.1	<0.1	<0.1
Jan.	0.1	0.2	<0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.2
Feb.	0.2	0.2	0.0	0.0	<0.1	0.0	0.0	<0.1	<0.1	0.0	<0.1	0.6	0.3
Mar.	0.1	0.2	0.0	<0.1	<0.1	<0.1	0.0	0.1	<0.1	<0.1	0.0	0.1	0.2
Apr.	0.0	0.1	0.1	<0.1	0.4	0.1	0.9	<0.1	0.1	0.0	0.0	<0.1	0.6
May	0.3	0.3	0.1	0.1	2.3	0.9	2.3	0.3	0.0	0.1	0.1	0.1	1.0
Jun.	0.3	0.7	1.0	0.2	1.2	1.2	1.7	0.1	0.1	0.1	0.1	0.1	0.5
Jul.	1.6	0.2	0.9	0.1	1.1	1.2	2.4	0.2	0.2	0.4	0.1	0.1	1.0
Aug.	4.4	1.0	0.1	0.1	1.5	0.5	1.4	<0.1	0.3	1.8	0.1	0.7	1.7
Sep.	2.8	0.3	0.2	0.0	0.3	0.2	0.4	<0.1	0.2	1.6	0.1	0.2	1.1
Oct.	0.2	0.1	<0.1	0.1	0.1	0.1	<0.1	<0.1	0.0	0.1	<0.1	0.1	0.5
Nov.	0.3	0.4	0.0	<0.1	<0.1	0.1	0.0	<0.1	<0.1	0.1	<0.1	<0.1	0.9
Dec.	1.8	0.6	0.0	0.0	<0.1	<0.1	<0.1	0.1	0.0	<0.1	<0.1	0.1	0.6
1973													
Jan.	0.4	0.3	0.0	0.0	0.0	0.1	0.0	0.1	0.0	<0.1	0.2	<0.1	0.5
Feb.	0.2	0.6	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.2	1.1
Mar.	0.3	0.4	0.0	<0.1	<0.1	0.0	0.0	<0.1	0.0	0.0	<0.1	0.1	0.3
Apr.	0.1	0.2	<0.1	<0.1	<0.1	0.1	0.5	0.0	0.0	0.0	<0.1	0.2	0.7
May	0.1	0.4	0.1	0.1	0.6	0.5	1.3	0.1	<0.1	<0.1	<0.1	0.2	1.3
Jun.	0.5	0.6	1.6	0.2	0.6	0.4	1.4	0.1	0.1	0.4	<0.1	0.3	1.7
Jul.	1.5	1.0	0.4	1.0	0.5	0.2	1.0	<0.1	0.1	1.1	0.0	0.5	2.2
Aug.	0.6	1.1	0.1	<0.1	0.2	<0.1	0.4	0.1	0.2	1.5	0.0	0.2	1.2
$\bar{X}$	0.8	0.4	0.2	<0.1	0.4	0.3	0.7	0.1	0.1	0.4	0.1	0.2	0.9

Note: The numbered columns represent the following predators: adults and immatures of (1) Geocoris spp. (mostly Geocoris punctipes), (2) Nabis spp., (3) Orius insidiosus, and (4) Chrysopa spp. (mostly C. rufilabris); adults of (5) Coleomegilla maculata and (6) Hippodamia convergens; (7) immatures of the large Coccinellidae; (8) adults of the small Coccinellidae; adults and immatures of (9) Carabidae and (10) Dermaptera; (11) adults of Formicidae; (12) other predaceous insects including adults and immatures of Podisus maculiventris, Jalysus spinosus, Reduviidae, and Hemerobiidae, and adults of Notoxus spp.; and (13) adults and immatures of Araneida. Estimates were generally from weekly inspections of whole plants on ca. 0.003-0.006 acre. However, infrequently they were from plant shakes or D-vac samples. Weekly estimates of the predator densities for each crop were multiplied by the percentage of the 8-acre system the crop occupied, and then added across crops. Weekly estimates were then averaged for each month for the estimates reported here.

[a]Numbers were estimated from D-vac samples of 0.03 acre.

Sources

Within the 8-acre system white clover (Table 25) was the major contributor to the predaceous arthropod groups presented in Table 24. White clover was in the system continuously and supported high densities of many predaceous arthropods. However, because white clover took longer to develop a comparable amount of foliage cover, prey species increased more rapidly in rye and wheat, and as a consequence these crops supported larger numbers of predaceous arthropods during the first winter. Crops (other than white clover) with high estimates of the selected predaceous arthropods were sweet corn, field corn, millet, soybeans and sorghum (Table 25).

Squash, pumpkins, tomatoes, cabbage, and wheat and rye had the lowest densities of the selected predaceous arthropods, and generally contributed the least to the predaceous arthropod complex. However, these crops were all in the 8-acre system for a short period of time, with the exception of tomatoes, or were flourishing during a cool period when most insects are not reproducing and developing rapidly. As mentioned previously, rye and wheat were, however, important in serving as reservoirs for several of the predator groups during the winter when other crops were absent from the system.

Crops with intermediate densities of the selected predaceous arthropods includes those with the highest densities of the cabbage looper and tobacco budworm. There were periods in these crops when a substantial number of predaceous arthropods were found, however, these increases in density of

Table 25.--Relative abundance of selected predaceous arthropods found in individual crops in 8-acre cropping system; abundance presented as monthly means of estimated number per acre in 1000's.

Month	Collards	Cabbage	Soybeans[a]	Flue-cured tobacco	Cigar-wrapper tobacco	Okra	White clover	Sweet corn	Field corn	Sorghum	Millet	Field peas
1971-72												
Dec.	0.0											
Jan.	0.0						0.1[b]					
Feb.	0.0						<0.1[b]					
Mar.	0.0	0.0					0.1[b]					
Apr.	0.9	1.6		1.4	0.9		18.0	2.0		3.6		
May	3.7	2.6		8.6	0.2		44.3	11.2	3.2	7.8	3.0[b]	
Jun.	3.7		1.3	5.2	8.1	12.5	30.3	17.3	15.3	4.7	3.0[b]	1.7
Jul.	3.0		4.6	0.4	14.9	5.5	22.4	9.8	16.9	7.0	50.2	10.7
Aug.	0.5		9.6	0.5		7.2	50.0	22.3	16.0	11.5	38.5	2.8
Sep.	1.7		10.5			4.2	21.5[b]			8.4		1.7
Oct.	1.5		2.0			1.4	3.1[b]			19.3		
Nov.	1.0						14.6					
Dec.	0.3						15.4					
1973												
Jan.	1.2						4.4					
Feb.	0.7						7.0					
Mar.	0.4	0.0		0.0			6.1					0.5
Apr.	0.5	0.2		0.2			11.3				4.6	1.1
May	11.7	2.0	0.5	0.5		1.8	34.8		0.9	18.2	7.6	9.8
Jun.	8.8	5.3	4.3	0.8		6.2	29.7		16.6	6.9	6.3	11.0
Jul.	9.3		17.0	2.3		10.0	35.0		18.1	8.9	26.7	
Aug.			29.7			8.7	22.0					
$\bar{x}$	2.5	1.7	8.8	2.0	6.0	5.1	18.5	12.5	12.4	7.9	22.3	4.9

Note: Weekly estimates were averaged to obtain these means. Estimates were generally from inspections of whole plants made once or twice daily on ca. 0.003-0.006 acre. Predators sampled include adults and immatures of Ceocoris spp. (mostly C. punctipes), Nabis spp., Orius insidiosus, Podisus maculiventris, Jalysus spinosus, Reduviidae, Chrysopa spp. (mostly C. rufilabris), Micromus spp., Coccinellidae (mostly Coleomegilla maculata, Hippodamia convergens, Scymnus loweri, and Diomus terminatus), Carabidae (mostly Calleida decora), Dermaptera (mostly Doru lineare), and adults of Notoxus spp., and Araneida.

[a]Some weekly estimates were from plant shakes of 0.003-0.006 acre.

[b]Weekly estimates obtained from D-vac samples (0.03 acre) were averaged to obtain these means.

Table 25.--Extended

Month	Peanuts	Bell peppers	Rye	Wheat	Tomatoes	Turnips	Pumpkins	Bush beans	Squash	Dahlia grass[b]	Roadside weeds[b]
1971-72											
Dec.			0.2[b]	0.1[b]						7.7	
Jan.			1.0[b]	1.4[b]						6.2	3.1
Feb.			1.6[b]	1.8[b]						0.6	1.6
Mar.			1.1[b]	1.5[b]	0.8					1.2	0.6
Apr.	3.0	1.4	0.9[b]	0.8[b]	1.5					1.3	0.8
May	1.5	1.3			1.5					2.2	1.4
Jun.	4.8	3.1			0.2					4.4	1.9
Jul.	9.8	5.8			4.1					1.4	5.1
Aug.		1.8					1.2	1.9	0.2	1.0	2.5
Sep.		1.8				2.0		2.3	1.3	3.4	0.9
Oct.				0.0		4.0				3.2	2.2
Nov.			0.8	2.5		7.2				2.0	1.0
Dec.										2.9	3.4
1973			0.9	1.0		2.7					
Jan.			2.7	1.8						0.4	0.1
Feb.			0.9	0.9						0.2	0.8
Mar.		0.0	1.0	1.4	0.6					0.2	0.7
Apr.	0.8	0.8			1.0					0.5	0.4
May	2.0	3.4			2.2					1.7	0.7
Jun.	7.4	4.2			2.3					1.5	2.2
Jul.										2.0	2.7
Aug.											
$\bar{x}$	4.2	2.4	1.3	1.3	1.6	4.0	1.2	2.1	0.7	2.2	1.7

total selected predaceous arthropods in these crops, usually reflected increases in density by a single predator group.

One predator group (earwigs) was also the reason for high densities of total selected predators in millet. However, in most crops with high densities of predaceous arthropods, several predator groups were responsible. Predaceous arthropod species were also varied in some crops with intermediate densities of the selected predaceous arthropods, i.e., okra, field peas, peanuts, and bell peppers.

Geocoris spp., which were recovered from crops of the 8-acre system, were mostly G. punctipes; however, Geocoris uliginosus (Say) was numerous in grassy situations. G. punctipes was a major predator of the total selected predaceous arthropod complex (Table 24) that occurred in white clover, soybeans, sweet corn, field corn, sorghum, millet, peanuts, field peas, okra, bell peppers, turnips, tomatoes, rye, and wheat. White clover was the major source of G. punctipes in the 8-acre system (Table 25) although sorghum, soybeans, millet, turnips, sweet corn, and field corn contributed numerous G. punctipes while they were in the system.

Rye and wheat did not support high densities of G. punctipes, or other predaceous arthropods, but certainly helped to maintain G. punctipes and some other predators, including Nabis spp., in the 8-acre system. G. punctipes maintained its numbers in rye and wheat from about mid-December to early April. Also, since G. punctipes increased to relatively high densities in sweet corn and field corn during the growing season of soybeans, and since corn was removed from the system before soybeans were, many G. punctipes probably moved into soybeans from corn.

Nabis spp. identified from the 8-acre system were mostly Nabis capsiformis Germar and Nabis roseipennis Reuter. Nabis spp. were major

predators in white clover, sweet corn, field corn, sorghum, okra, soybeans, tomatoes, field peas, rye, and wheat. White clover was the major contributor of Nabis spp. to the 8-acre system, although rye and wheat were important in the winter months, and Nabis spp. were abundant in field peas, soybeans, and sweet corn in the spring and summer.

Of large coccinellids, C. maculata was the most common species; however, H. convergens was also common. Cycloneda spp. and Olla abdominalis (Say) were found less frequently.

C. maculata was a major predator found in white clover, sweet corn, field corn, sorghum, collards, cabbage, flue-cured tobacco, cigar-wrapper tobacco, peanuts, field peas, and okra. White clover was the most important source of C. maculata for the 8-acre system; however, collards, sorghum, corn, and tobacco were also very important sources of this coccinellid. Rye and wheat were not important in sustaining overwintering C. maculata; however, C. maculata did begin to increase in rye and wheat just prior to removal of these crops from the system in both 1972 and 1973.

C. maculata occurred consistently in the system from ca. March-October. It is apparently able to survive and reproduce on a number of foodstuffs including animal food (lepidopterous eggs and larvae, aphids, etc.) and plant food (pollen, spores, lichens, etc.) (Webster 1880; Forbes 1883; Riley 1893; Szumkowski 1952a, b; Smith 1960). Conrad (1956) found that corn pollen was a favored food of C. maculata. Perhaps this accounts partly for its stable occurrence in the system and its abundance in corn.

C. maculata began increasing in numbers in white clover early in the spring, and adults reached densities of >20,000 per acre during this season. This crop undoubtedly served to maintain

numbers of these coccinellids in the system and provided a source of adults that moved into collards and tobacco when these crops were later established.

Occurrence of H. convergens was similar to that of C. maculata. However, it occurred at lower densities, and it was generally found in the system at stable levels only from ca. May-August. It may be that the population of H. convergens at Quincy goes into estivation in the late summer as suggested by Neal (1974), or rather, into an estivo-hibernation similar to that which occurs in populations of this species in the far western U.S. (Hagen 1962) and in Arkansas (Stewart et al. 1967). Stewart et al. (1967) stated that estivation for populations of this species in Arkansas "appeared to be faculative and associated with low prey populations"; this may be the case in northern Florida also. Furthermore, in his review on predaceous coccinellids, Hagen (1962) states ". . . H. convergens exhibits either a faculative univoltine or multivoltine condition which appears to be correlated more closely to the abundance of aphids rather than to seasonal environmental changes, except for the always-occurring winter hibernation."

H. convergens was the most abundant large lady beetle in cigar-wrapper tobacco, particularly, in July. This was unusual for the cropping system, since in all other crops, except for perhaps flue-cured tobacco, and during most other periods, C. maculata was the major large coccinellid.

Scymnus loewii Mulsant and Diomus terminatus (Say) were the most common small coccinellids in the 8-acre system, and were apparently least abundant during the warmer months from June-October. Scymnus socer Lecont were less common and found early in the year, primarily in May and June. Hyperapis sp. were rare.

Relative to the large coccinellids, the small coccinellids were not

"major" predators associated with cabbage loopers, soybean loopers, or tobacco budworms in the 8-acre system. They were most abundant in white clover, rye, and wheat during the winter months, and sorghum during the summer months.

O. insidiosus was the most common anthocorid found although 3 other species of anthocorid were found, including 1 which was common late in the soybean-growing season. O. insidiosus was a major predator in white clover, sweet corn, field corn, and sorghum, which were all major sources of it in the 8-acre system. In 1973, however, numerous O. insidiosus were also found from whole plant inspections of millet, soybeans, and tomatoes.

The most common species of Chrysopa found in the 8-acre system was Chrysopa rufilabris, although several other species were also found. Very few adults or larvae of any Chrysopa spp. were found in any crop other than sweet corn in 1972 and collards in 1973. However, numerous adults of Chrysopa spp. were observed during some nights in sorghum and field corn (and sweet corn) during July and August of 1972.

Also, numerous eggs of Chrysopa spp., mostly C. rufilabris, were collected in soybeans, okra, field peas, and collards in 1973. In collards, per acre estimates for eggs were highest in mid-June in 1972 and early June during 1973. A few eggs of Chrysopa spp. were parasitized (by Trichogramma perkinsi and T. semifumatum) and perhaps they were heavily preyed upon. However, I believe improved sampling techniques would have yielded more adults and larvae.

Similar to results on Chrysopa spp., few ground beetles were found on foliage of crops of the 8-acre system; however, Calleida decora were often found in soybeans plus many other crops, and Leptotrachelus dorsalis (F.)

were found in corn and sorghum on a number of sample dates. Ground beetles were most abundant in soybeans.

The only earwig which was collected in large numbers on the foliage of crops was Doru lineare. It occurred at moderate densities in soybeans, sweet corn, sorghum, and field corn, but was particularly abundant in millet.

Notoxus spp., including N. monodon monodon, were found infrequently in the 8-acre system. However, densities of Notoxus spp. of up to 64,000 per acre were estimated from D-vac samples of bell peppers in the 1-acre shade.

Similar to Notoxus spp., relatively few Podisus maculiventris, Jalysus spinosus, assassin bugs, or brown lacewings were found in any crops. Determinations by Dr. Catherine Tauber (Cornell University, Ithaca, NY) did reveal that Micromus subacticus Walker, was the more common of 2 brown lacewing species which were collected primarily in rye, wheat, clover, bahia grass, and shade tobacco. As a group, the "other predaceous arthropods" (Table 24), i.e., P. maculiventris, J. spinosus, assassin bugs, Micromus spp., and Notoxus spp. were most abundant in soybeans and white clover.

Bahia grass and the wild hosts near the cropping system did support numerous ants, primarily imported fire ants, Solenopsis invicta Buren, but few were found from whole plant inspections, or D-vac samples of cultivated crops of the 8-acre system. Therefore, ants probably did not have a great direct impact on the eggs (or larvae) of cabbage loopers, soybean loopers, or tobacco budworms. This would contrast with what was observed by Whitcomb and Bell (1964) on eggs of Heliothis spp. in Arkansas cotton. However, since predaceous arthropods were not sampled on the ground level

of the 8-acre system, ants may have destroyed some tobacco budworm pupae. In the 1-acre shade, which was surrounded by weeds on uncultivated land, ants were found on most sampling dates in all 7 crops (Section II) at densities estimated at a maximum of 4830 per acre on cabbage.

Relative to the other groups discussed, spiders as a group were abundant in most crops of the 8-acre system. They were most consistently at high densities in white clover, and there was probably considerable movement from this crop into collards and soybeans, and some other crops of the system. Spiders were absent or at low densities in collards, rye, and wheat during the winter, but after white clover was well established in the cropping system and had attained a substantial complex of insects, moderately high densities of spiders were associated with this crop during the winter of 1972-73. Low densities of spiders were found in peanuts.

White clover was the major source of predaceous arthropods in the 8-acre system and G. punctipes was probably the major predaceous arthropod species associated with soybean loopers, tobacco budworms, and/or cabbage loopers in the 8-acre system. However, other crops and other predators were often more important in acting on or interacting with the 3 target pests than white clover and/or G. punctipes.

Predators Associated with Cabbage Looper

Collards and cabbage, the crops possessing most of the cabbage loopers, had relatively low numbers of total selected predaceous arthropods when compared to most other crops of the 8-acre system (Table 25). Coleomegilla maculata was, however, found in cabbage or collards during most seasons except winter and early spring (Tables 26 and 27).

Highest estimates in collards were during late May in 1972 (1830 per acre) and early May in 1973 (2710/acre)(Table 27). Hippodamia convergens

Table 26.--Relative and seasonal abundance of selected predaceous arthropods in cabbage; abundance presented as weekly means of estimated number per acre in 1000's.

Date (week of)	1. Geocoris	2. Nabis	3. Orius[a]	4. Chrysopa[a]	5. Coleomegilla	6. Hippodamia	7. Lady beetle larvae	8. Scymnus	9. Ground beetles	10. Earwigs	11. Other predators	12. Spiders
1972												
Mar. 12												
Apr. 2[b]		0.0			0.0	0.0	0.0		0.0			0.0
9		0.0			0.0	0.0	0.0		0.0			0.2
16		0.0			0.0	0.2	0.1		0.0			1.0
23	None	0.2	None	None	0.2	0.0	0.4	None	0.0	None	None	3.5
30	found	0.0	found	found	0.0	0.3	0.7	found	0.0	found	found	1.8
May 7		0.0			0.5	0.2	0.3		0.0			0.4
14		0.0			0.9	0.3	0.3		0.0			0.9
21		0.0			1.3	0.2	0.0		0.0			2.3
1973												
Mar. 28		0.0			0.0	0.0	0.0		0.0			0.0
Apr. 1		0.0			0.0	0.0	0.0		0.0			0.7
8,15		0.0			0.0	0.0	0.0		0.0			0.0
22		0.0			0.0	0.0	0.0		0.0			0.2
29	None	0.0	None	None	0.0	0.0	0.0	None	0.0	None	None	0.2
May 6	found	0.0	found	found	0.0	0.0	0.0	found	0.0	found	found	0.0
13		0.0			0.0	0.0	0.0		0.0			2.0
20		0.0			0.0	1.0	1.5		0.0			3.2
27		0.0			0.0	0.0	0.0		0.0			0.3
Jun. 10		0.2			0.2	0.2	3.5		0.8			0.5

Note: The numbered columns represent the following predators: adults and immatures of (1) Geocoris spp. (mostly Geocoris punctipes), (2) Nabis spp., (3) Orius insidiosus, and (4) Chrysopa spp. (mostly C. rufilabris); adults of (5) Coleomegilla maculata and (6) Hippodamia convergens; (7) immatures of the large Coccinellidae; (8) adults of the small Coccinellidae; adults and immatures of (9) Carabidae and (10) Dermaptera; (11) other predaceous insects including adults and immatures of Podisus maculiventris, Jalysus spinosus, Reduviidae, and Hemerobiidae, and adults of Notoxus spp.; and (12) adults and immatures of Araneida. None were found if columns are absent. Estimates were generally from weekly inspections of whole plants on ca. 0.003-0.006 acre.

[a] D-vac samples from April 9-May 21 yielded no Orius spp. or Chrysopa spp.

[b] Samples were taken during the weeks of March 12, 19, 26 and April 2.

Table 27.--Relative and seasonal abundance of selected predaceous arthropods in collards; abundance presented as weekly means of estimated number per acre in 1000's.

Date (week of)	1. Geocoris	2. Nabis	3. Orius	4. Chrysopa	5. Coleomegilla	6. Hippodamia	7. Lady beetle larvae	8. Scymnus	9. Ground beetles	10. Earwigs	11. Other predators	12. Spiders
1971-72												
Dec. 5-Apr. 9[a]	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0(0.0)	0.0(0.0)	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0(0.0)	0.1(0.2)	0.3	0.0	0.1	0.0	0.0	0.0	0.3	1.0
30	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.1	0.0	0.0	2.0
May 7	0.0	0.0	0.0(-)	0.0(-)	0.7	0.1	2.0	0.0	0.0	0.0	0.0	3.2
14	0.0	0.2	0.0(0.0)	0.0(0.0)	1.5	0.8	0.0	0.0	0.0	0.0	0.0	4.3
21	0.0	0.0	0.0(0.0)	0.0(0.0)	1.2	0.2	0.0	0.0	0.0	0.0	0.0	1.2
28	0.0	0.0	0.0(0.0)	0.0(0.0)	0.5	0.0	5.0	0.0	0.0	0.0	0.0	0.8
Jun. 4	0.0	0.0	0.0(0.0)	0.0(0.0)	0.8	0.2	4.2	0.0	0.0	0.0	0.0	3.3
11	0.0	0.2	0.0(0.1)	0.0(0.0)	0.8	0.0	0.8	0.0	0.0	0.0	0.0	1.2
18	0.0	0.2	0.0(-)	0.2(-)	1.1	0.3	0.0	0.0	0.0	0.0	0.0	0.4
25	0.0	0.0	0.0(0.0)	0.0(-)	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Jul. 2	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.2	0.0	0.0	0.0	0.0	1.0
9	0.0	0.0	0.0(0.0)	0.0(0.1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
16	0.0	0.0	0.0(0.0)	0.0(0.0)	0.6	0.6	0.1	0.0	0.0	0.0	0.0	0.3
23	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	2.2	5.2	0.0	0.0	0.0	0.0	2.0
Aug. 13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
20	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.2
27	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Sep. 3	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
17	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8
24	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Oct. 1	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0(0.0)	0.0(0.0)	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.3
15	0.0	0.0	0.0(-)	0.0(-)	0.3	0.7	0.0	0.0	0.0	0.0	0.0	2.5
22	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
29	0.2	0.3	0.0(0.0)	0.0(0.0)	0.1	0.0	0.0	0.0	0.0	0.2	0.0	2.8
Nov. 5	0.0	0.0	0.0(-)	0.0(-)	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.7
12	0.0	0.0	0.0(-)	0.0(-)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0(-)	0.0(-)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec. 3	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.2	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.3	0.0(-)	0.0(-)	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2
24	0.2	0.2	— (0.0)	— (0.0)	<0.1	0.0	<0.1	0.3	0.0	0.0	0.2	0.2
31	0.4	0.2	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0

Table 27.—Continued

Date (week of)	1. Geocoris	2. Nabis	3. Orius	4. Chrysopa	5. Coleomegilla	6. Hippodamia	7. Lady beetle larvae	8. Scymnus	9. Ground beetles	10. Earwigs	11. Other predators	12. Spiders
1973												
Jan. 7	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
14	1.2	0.4	0.0(0.0)	0.0(0.0)	0.0	0.2	0.0	0.0	0.0	0.0	0.0	3.1
21	0.0	0.2	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb. 4	0.2	0.2	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
11	0.2	0.4	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.2	0.2	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.2	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Mar. 4	0.0	0.2	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.4
11	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
25	0.0	0.2	0.0(-)	0.0(-)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apr. 1	0.2	0.2	0.0(0.0)	0.2(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6
8	0.0	0.0	0.0(0.0)	0.2(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
15	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0(0.0)	0.0(0.1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	2.0	0.0(0.0)	0.1(0.0)	0.0	0.0	2.0	0.0	0.0	0.0	0.2	1.6
May 6	0.0	0.0	0.0(0.0)	0.0(0.0)	0.6	0.0	0.2	0.0	0.0	0.0	0.0	0.0
13	0.0	0.1	0.0(0.0)	0.0(0.0)	1.7	0.7	0.7	0.0	0.0	0.0	0.0	2.6
20	0.0	0.8	0.0(0.1)	0.5(0.3)	2.2	1.4	11.9	0.0	0.0	0.0	1.7	2.5
27	0.2	1.9	0.0(0.0)	1.0(0.1)	2.7	0.4	12.5	0.0	1.5	0.4	0.2	4.0
Jun. 3	0.0	0.0	0.0(0.0)	1.2(0.0)	2.1	0.4	1.7	0.0	0.0	0.0	0.8	1.2
10	0.0	0.4	0.0(0.0)	1.2(0.1)	2.5	0.0	4.6	0.0	0.0	0.0	0.0	4.6
17	0.0	0.6	0.0(0.0)	0.8(0.0)	1.2	0.2	5.6	0.0	0.0	0.0	0.2	1.9
24	0.0	0.0	0.0(0.0)	0.0(0.0)	1.9	0.6	3.1	0.2	0.0	0.0	0.0	1.2
Jul. 1	0.0	0.2	0.0(0.0)	0.0(0.0)	1.0	0.8	0.8	0.0	0.0	0.0	0.2	2.1
8	0.0	0.0	0.0(0.0)	0.0(0.0)	0.9	0.3	1.6	0.0	0.0	0.4	0.0	1.6
15	0.2	0.2	0.0(0.0)	0.0(0.0)	2.5	0.8	0.8	0.0	0.0	0.3	1.2	5.5

Note: The numbered columns represent the following predators: adults and immatures of (1) Geocoris spp. (mostly Geocoris punctipes), (2) Nabis spp., (3) Orius insidiosus, and (4) Chrysopa spp. (mostly C. rufilabris); adults of (5) Coleomegilla maculata and (6) Hippodamia convergens; (7) immatures of the large Coccinellidae; (8) adults of the small Coccinellidae; adults and immatures of (9) Carabidae and (10) Dermaptera; (11) other predaceous insects including adults and immatures of Podisus maculiventris, Zelus spinosus, Reduviidae, and Hemerobiidae, and adults of Notoxus spp.; and (12) adults and immatures of Araneida. Estimates were generally from weekly inspections of whole plants on ca. 0.003-0.006 acre. However, those in parenthesis were from D-vac samples of 0.03 acre.

[a]Samples were taken during the weeks of December 12, 26; January 2, 16, 23, 30; March 5, 12, 26; and April 2, 9.

[b]Data were from weekly D-vac samples of 0.03 acre.

was found less frequently and occurred at lower densities than C. maculata. Spiders were found at fairly constant levels in collards except during the winter and early spring (Table 27). Estimated density of spiders in this crop were highest in mid-May of 1972 (4330 per acre) and during the last week collards were sampled in 1973 (5520 for July 15). In D-vac samples during 1972 and 1973 Nabis spp. were found at low density levels during most of the year in collards. Highest densities were estimated for Geocoris punctipes in July and Nabis spp. in May. Few of these Hemiptera were found in whole plant inspections (Table 27).

In spring cabbage, C. maculata, H. convergens, and spiders were the major groups of predaceous arthropods (Table 26). Total selected predaceous arthropods and the large coccinellids generally increased to highest densities after relatively high densities of eggs and small larvae of cabbage looper occurred (Fig. 17); however, the predaceous arthropods were probably largely dependent on other prey. In addition to high densities of cabbage looper in cabbage, there were also high densities of "alternate prey" such as imported cabbageworms.

Densities of predaceous arthropods were comparable to those of medium and large larvae of cabbage looper but much lower than those of eggs and small larvae. Medium and large larvae were present at much lower densities than eggs and small larvae (Fig. 17); however, mortality was probably due largely to factors other than predation. Peak densities of predaceous arthropods lagged far behind initial buildup of eggs and larvae of cabbage loopers in 1973 (Fig. 17) in contrast to 1972, but reached densities similar to those in 1972.

In collards, results were generally similar to those in cabbage (Table 27 and Fig. 18). However, predaceous arthropods increased to

Fig. 17.--Relative number of eggs plus small larvae of cabbage looper, medium plus large larvae of cabbage looper, total selected predaceous arthropods, and large predaceous coccinellids in cabbage. Predators sampled included adults and immatures of Geocoris spp., Nabis spp. Orius insidiosus, Podisus maculiventris, Jalysus spinosus, Reduviidae, Chrysopa spp., Micromus spp., predaceous Coccinellidae, Carabidae, Dermaptera, and adults of Notoxus spp., and Araneida. Sampling was by "whole plant" inspections.

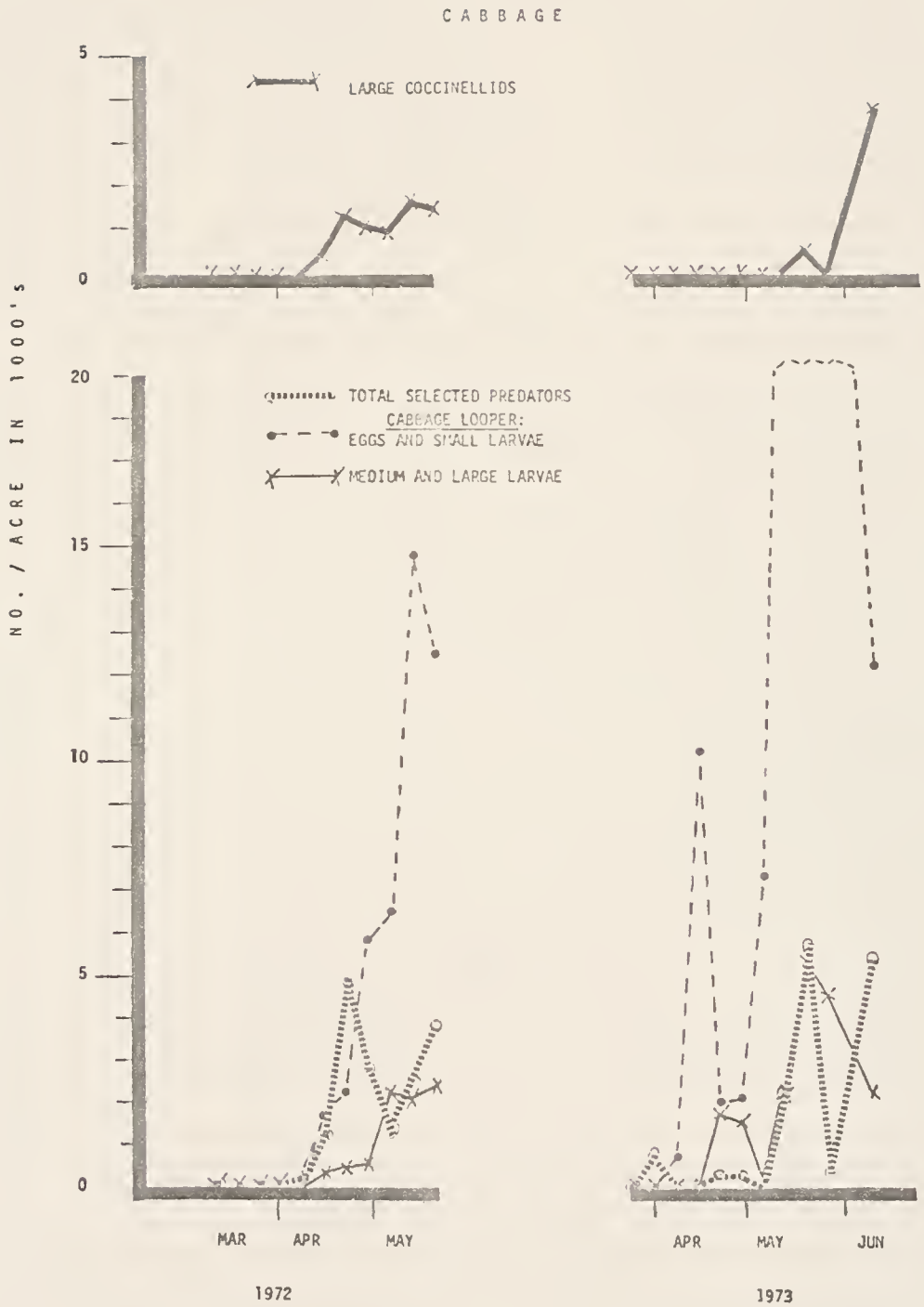
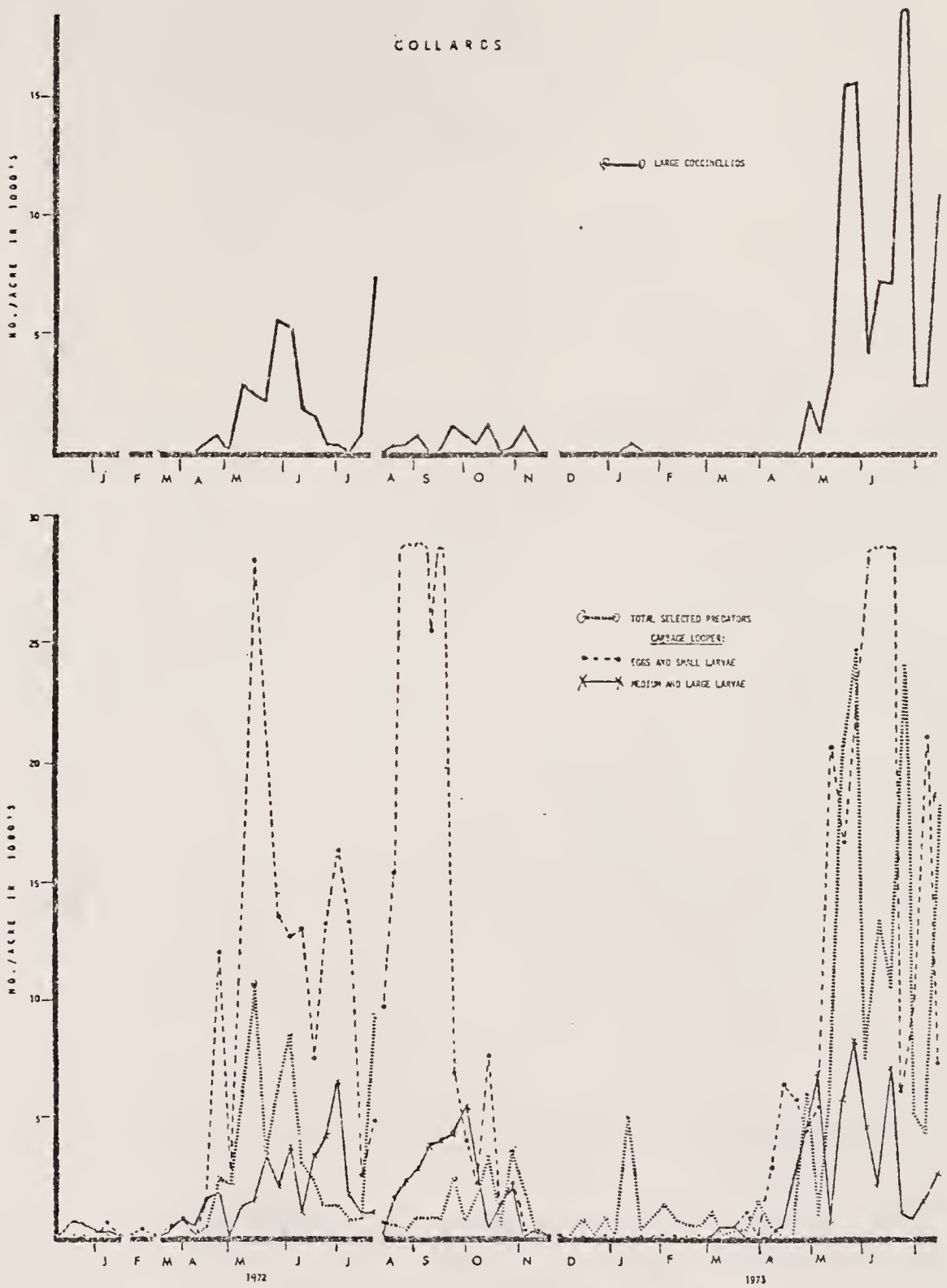

CABBAGE
LARGE COCCINELLIDS
TOTAL SELECTED PREDATORS
CABBAGE LOOPER:
EGGS AND SMALL LARVAE
MEDIUM AND LARGE LARVAE
NO. / ACRE IN 1000's
5
0
20
15
10
5
0
MAR
APR
MAY
APR
MAY
JUN
1972
1973

Fig. 18.--Relative number of eggs plus small larvae of cabbage looper, medium plus large larvae of cabbage looper, total selected predaceous arthropods, and large predaceous coccinellids in collards. Predators sampled included adults and immatures of Geocoris spp., Nabis spp. Orius insidiosus, Podisus maculiventris, Jalysus spinosus, Reduviidae, Chrysopa spp., Micromus spp., predaceous Coccinellidae, Carabidae, Dermaptera, and adults of Notoxus spp., and Araneida. Sampling was by "whole plant" inspections.


COLLARDS
LARGE COCCINELLIDS
NO./ACRE IN 1000'S
J F M A M J J A S O N D J F M A M J
TOTAL SELECTED PREDATORS
CABBAGE LOOPER:
EGGS AND SMALL LARVAE
PUPDEN AND LARGE LARVAE
1972
1973

higher densities in the spring than they did in cabbage, and in this more continuous crop of the system, abundance of predaceous arthropods increased considerably from 1972 to 1973 (Fig. 18). Increase in number of lady beetles parallelled the increase of total predators in both 1973 and 1972; however, G. punctipes were found more frequently, though at lower densities, in 1973 than 1972.

In late July and early August, 1972, when the old crop of collards was replaced by a new one, numbers of predaceous arthropods remained at relatively low density levels until the following spring. Even so, the number of large and medium cabbage looper larvae was far lower than the initial number of eggs and small larvae.

Coccinellids, especially C. maculata, and spiders were the major predator groups in collards (Table 27). They probably preyed on and helped suppress medium and large larvae to numbers far below those of eggs and small larvae that were initially present. However predation was perhaps only a minor factor in total cabbage looper mortality within the 8-acre cropping system.

In crops, such as flue-cured tobacco and okra, with only incidental records of the cabbage looper occurrence, densities of the cabbage looper probably were low, mostly because of non-preference of the cabbage looper (Section II). In white clover, low densities may have been a result of non-preference plus some predation. The Plusiinae occurring in soybeans and tomatoes will be discussed as soybean loopers since this was the predominant Plusiinae species in these crops.

Predators Associated with Soybean Looper

In contrast to what occurred in collards and cabbage, in soybeans--the primary crop possessing soybean loopers--predators reached relatively

high density levels; and estimates of both eggs plus small larvae of the soybean looper, and medium plus large larvae of this pest, were at densities much lower than either total selected predaceous arthropods or predaceous Hemiptera (Fig. 19). There were a number of variables contributing to the maintenance of low densities of the soybean looper in soybeans, but the abundance of predaceous arthropods in this crop surely was a major factor. In addition, the relatively complex predator group in soybeans (Table 28) was surely more effective in maintaining pressure on the Plusiinae in soybeans, than that associated with Plusiinae in collards and cabbage.

Geocoris punctipes, Nabis spp., and spiders were the most abundant predators sampled in soybeans. All 3 groups tended to be mostly uniformly abundant throughout the soybean-growing season, although Nabis spp. did fluctuate considerably.

Similar to results in collards, adults and larvae of Chrysopa spp. were seldom found in whole plant inspections (Table 28), or D-vac samples but eggs were numerous in whole plant inspections of soybeans. Other predators moderately abundant on the foliage of soybeans were the predaceous coccinellids, earwigs, ground beetles, predaceous pentatomids, and assassin bugs.

Peucetia viridans (Hentz) was one of the most common of spiders found in soybeans. However, numerous species occurred in this crop which have not been identified.

G. punctipes and Nabis spp. were found at fairly consistent densities in soybeans from July through August. Contrary to the results of Neal (1974), Geocoris spp. was usually the predominant genus found in whole plant inspections (Table 28) and D-vac samples of soybeans. In

Fig. 19.--Relative number of eggs plus small larvae of soybean looper, medium plus large larvae of soybean looper, total selected predaceous arthropods, and selected predaceous Hemiptera in soybeans. Predators sampled included adults and immatures of Geocoris spp., Nabis spp. Orius insidiosus, Podisus maculiventris, Jalysus spinosus, Reduviidae, Chrysopa spp., Micromus spp., predaceous Coccinellidae, Carabidae, Dermaptera, and adults of Notoxus spp., and Araneida. Sampling was by "whole plant" inspections and plant shakes.

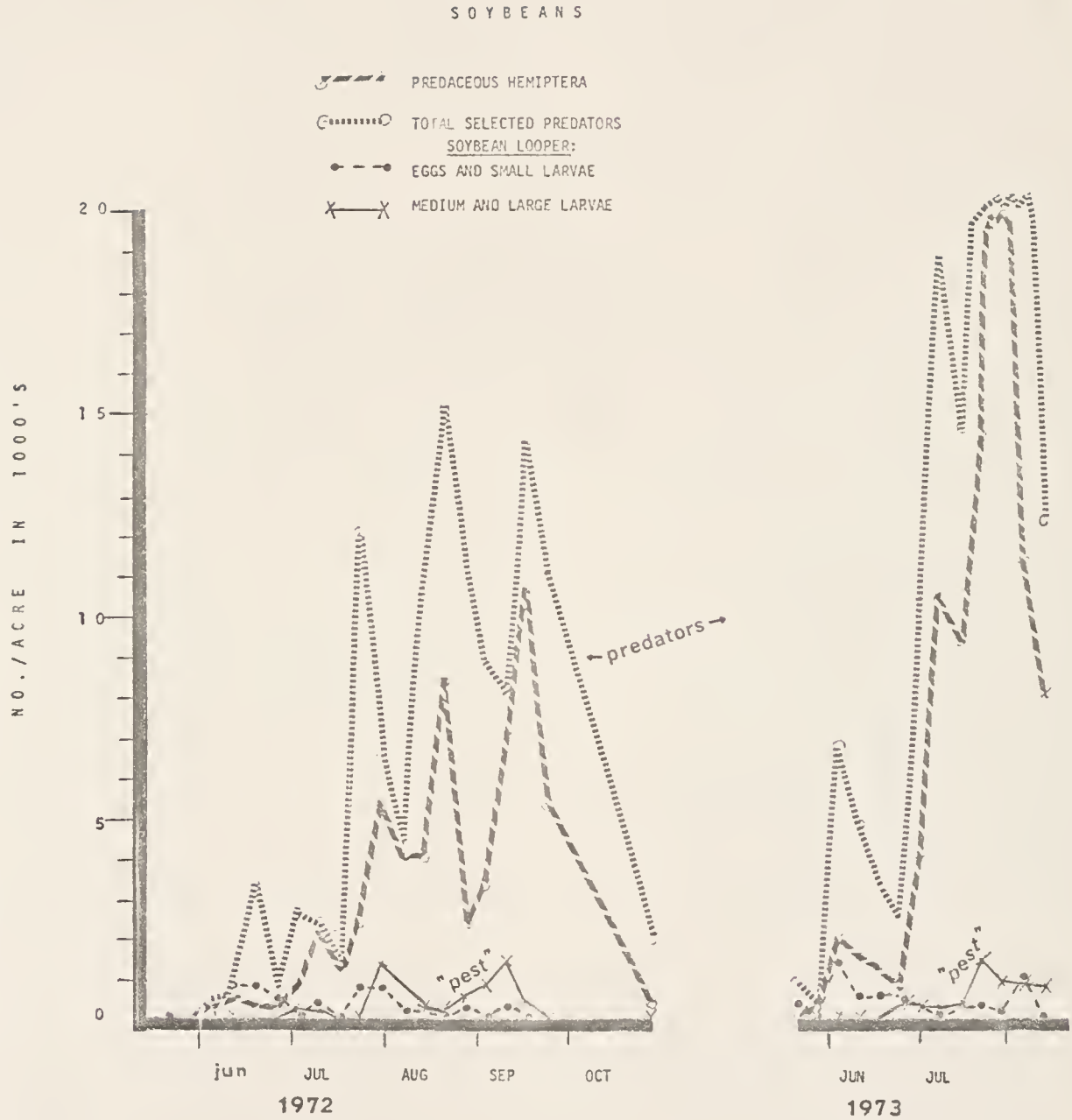

SOYBEANS
PREDACEOUS HEMIPTERA
TOTAL SELECTED PREDATORS
SOYBEAN LOOPER:
EGGS AND SMALL LARVAE
MEDIUM AND LARGE LARVAE
NO./ACRE IN 1000'S
20
15
10
5
0
predators
"pest"
JUN
JUL
AUG
SEP
OCT
1972
JUN
JUL
1973

Table 28.--Relative and seasonal abundance of selected predaceous arthropods in soybeans; abundance presented as weekly means of estimated number per acre in 1000's.

Date (Week of)	1. Geocoris	2. Nabis	3. Orius	4. Chrysopa	5. Coleomegilla	6. Hippodamia	7. Lady beetle larvae	8. Scymnus	9. Ground beetles	10. Earwigs	11. Other predators	12. Spiders
1972												
Jun. 4	0.1	0.2	0.0(0.0)	0.0(0.0)	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.4	0.0(0.0)	0.0(0.0)	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
18	0.2	0.0	0.0(0.2)	0.0(0.0)	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.2
25	0.1	0.2	0.0(0.1)	0.0(0.3)	0.1	0.1	0.0	0.0	0.2	0.0	0.0	0.1
Jul. 2	0.7	0.2	0.0(0.1)	0.0(0.0)	0.5	0.5	0.0	0.0	0.0	0.0	0.1	0.7
9	1.5	0.4	0.0(0.1)	0.1(0.1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
16	1.4	0.0	0.0(0.1)	0.0(0.1)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	1.5	1.2[a]	0.0(0.1)	0.8(0.1)	1.2[a]	0.3	0.8[a]	0.0	0.3	0.0	0.7[a]	6.2[a]
30	3.6	1.4	0.0(0.0)	0.0(0.1)	0.6	0.0	0.3[a]	0.0	0.0	0.0	0.2	0.4
Aug. 6	3.7	0.2	0.0(0.1)	0.0(0.0)	0.0	0.0	0.2	0.0	0.2[a]	0.0	0.2	0.0
13	3.6	0.1	0.0(0.0)	0.1(0.0)	0.7	0.2	0.7[a]	0.0	1.7[a]	0.2	0.3	3.1
20	7.3	0.8	0.0(0.0)	0.0(0.0)	1.4	0.4	0.3[a]	0.0	0.2	1.0	0.2	3.3
27	1.3	0.0	0.0(0.1)	0.0(0.0)	0.3	0.5	0.8[a]	0.0	0.8	0.5	1.0	6.0[a]
Sep. 3	2.3	0.7	0.0(0.0)	0.0(0.0)	0.2	0.2	0.0	0.0	1.2	1.0	0.3	3.0
10	6.6	0.2	0.0(0.0)	0.0(0.1)	0.0	0.0	0.2	0.0	0.1	0.0	0.3	0.7
17	10.0	0.2	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.2	0.5	0.5	2.8
24	4.7	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0	1.0	0.6	3.7
Oct. 29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7[a]
1973												
May 20	0.0	0.0	0.0(0.0)	0.0(0.0)	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.4
27	0.0	0.0	0.2(0.3)	0.0(0.0)	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Jun. 3	0.0	0.0	2.0(0.0)	0.0(0.0)	0.0	0.0	1.3	0.0	0.0	0.0	1.0	2.3
10	0.0	0.2	2.3(0.0)	0.0(0.0)	0.0	0.5	0.0	0.0	0.7	0.0	0.2	0.8
17	1.2	0.0	0.1(0.6)	0.2(0.0)	0.0	0.7	0.3	0.0	0.0	0.0	0.0	0.8
24	0.2	0.3[a]	0.0(0.0)	0.1(0.0)	0.3[a]	0.3	0.0	0.0[a]	0.0[a]	0.0[a]	0.2[a]	1.0[a]
Jul. 1	2.5	1.0[a]	0.2(0.0)	0.0(0.1)	0.2[a]	0.2	0.2[a]	0.2[a]	1.0[a]	0.2[a]	0.5[a]	4.0[a]
8	4.7[a]	4.6[a]	0.5(0.0)	0.2(0.0)	0.0[a]	0.0[a]	1.8[a]	0.0[a]	1.0[a]	0.2[a]	3.0[a]	2.8[a]
15	5.3[a]	2.7[a]	0.8(-)	0.6(-)	0.2[a]	0.0[a]	0.3[a]	0.0[a]	0.7[a]	0.6[a]	1.3[a]	2.7[a]
22	5.3[a]	7.5[a]	0.3(0.0)	0.0(0.0)	0.1[a]	0.0	2.3[a]	0.0	1.0[a]	0.9[a]	2.1[a]	5.3[a]
29	8.2[a]	14.2[a]	0.8(0.0)	0.0(0.0)	1.5[a]	0.2	6.0[a]	0.0	3.0[a]	6.0[a]	6.8	4.8
Aug. 5	3.2[a]	7.7[a]	0.0[a]	0.0[a]	0.5[a]	0.2[a]	1.7[a]	0.0[a]	0.7[a]	1.2[a]	1.3[a]	8.0[a]
12	3.0[a]	3.3[a]	0.5[a]	0.0[a]	0.2[a]	0.0[a]	0.5[a]	0.0[a]	0.7[a]	1.0[a]	1.7[a]	1.5[a]

Note: The numbered columns represent the following predators: adults and immatures of (1) Geocoris spp. (mostly Geocoris punctipes), (2) Nabis spp., (3) Orius insidiosus, and (4) Chrysopa spp. (mostly C. rufilabris); adults of (5) Coleomegilla maculata and (6) Hippodamia convergens; (7) immatures of the large Coccinellidae; (8) adults of the small Coccinellidae; adults and immatures of (9) Carabidae and (10) Dermaptera; (11) other predaceous insects including adults and immatures of Podisus maculiventris, Jalysus spinosus, Reduviidae, and Hemerobiidae, and adults of Notoxus spp.; and (12) adults and immatures of Araneida. Estimates were generally from weekly inspections of whole plants on ca. 0.003-0.006 acre.

[a]Numbers were estimated from plant shakes of 0.003-0.006 acre.

whole plant inspections estimates of Geocoris spp. in soybeans ranged from 0-10,000 per acre in 1972 and 0-8,250/acre in 1973. Highest estimates were in September of 1972 and late July of 1973 (when estimates were not taken after early August). Estimates for densities of Nabis spp. from whole plant inspections of soybeans ranged from 0-1420 per acre in 1972 and 0-14,250/acre in 1973 (Table 28). Highest estimates were in late July of both years.

Whole plant inspection data indicates spiders were most numerous in soybeans during late July (ca. 6170 per acre) and early September (ca. 8000/acre) during 1972 and 1973, respectively (Table 28). Coleomegilla maculata was most abundant during the week of August 20 during 1972 and during the week of July 29 in 1973. Density of Hippodamia convergens was low throughout the season. Peak estimates for ground beetles and Dermaptera occurred during approximately the same periods as those for C. maculata (Table 28).

During weeks they were found, eggs of Chrysopa spp. were estimated at densities that ranged from 170 per acre (during the week of June 11) to 9250/acre (during the week of July 9) in 1972. During 1972 eggs of Chrysopa spp. were found during 14 of 18 sample weeks. Estimates were lower in 1973 (250-4000/acre); and eggs were found during only 7 of 13 sample weeks.

In tomatoes Plusiinae were estimated at lower levels than they were in soybeans, with the exception of 1 date (Fig. 20). However, predator abundance was much less than in soybeans (Fig. 20) and the predator complex was much simpler (Table 29). The only predator group substantial in abundance other than spiders were the predaceous Hemiptera (Fig. 20). Only a few coccinellids were found and eggs of Chrysopa spp. were found

Fig. 20.--Relative number of eggs plus small larvae of Plusïnae, medium plus large larvae of Plusiinae, total selected predaceous arthropods, and selected predaceous Hemiptera in tomatoes. Predators sampled included adults and immatures of Geocoris spp., Nabis spp. Orius insidiosus, Podisus maculiventris, Jalysus spinosus, Reduviidae, Chrysopa spp., Micromus spp., predaceous Coccinellidae, Carabidae, Dermaptera, and adults of Notoxus spp., and Araneida. Sampling was by "whole plant" inspection and D-vac samples.

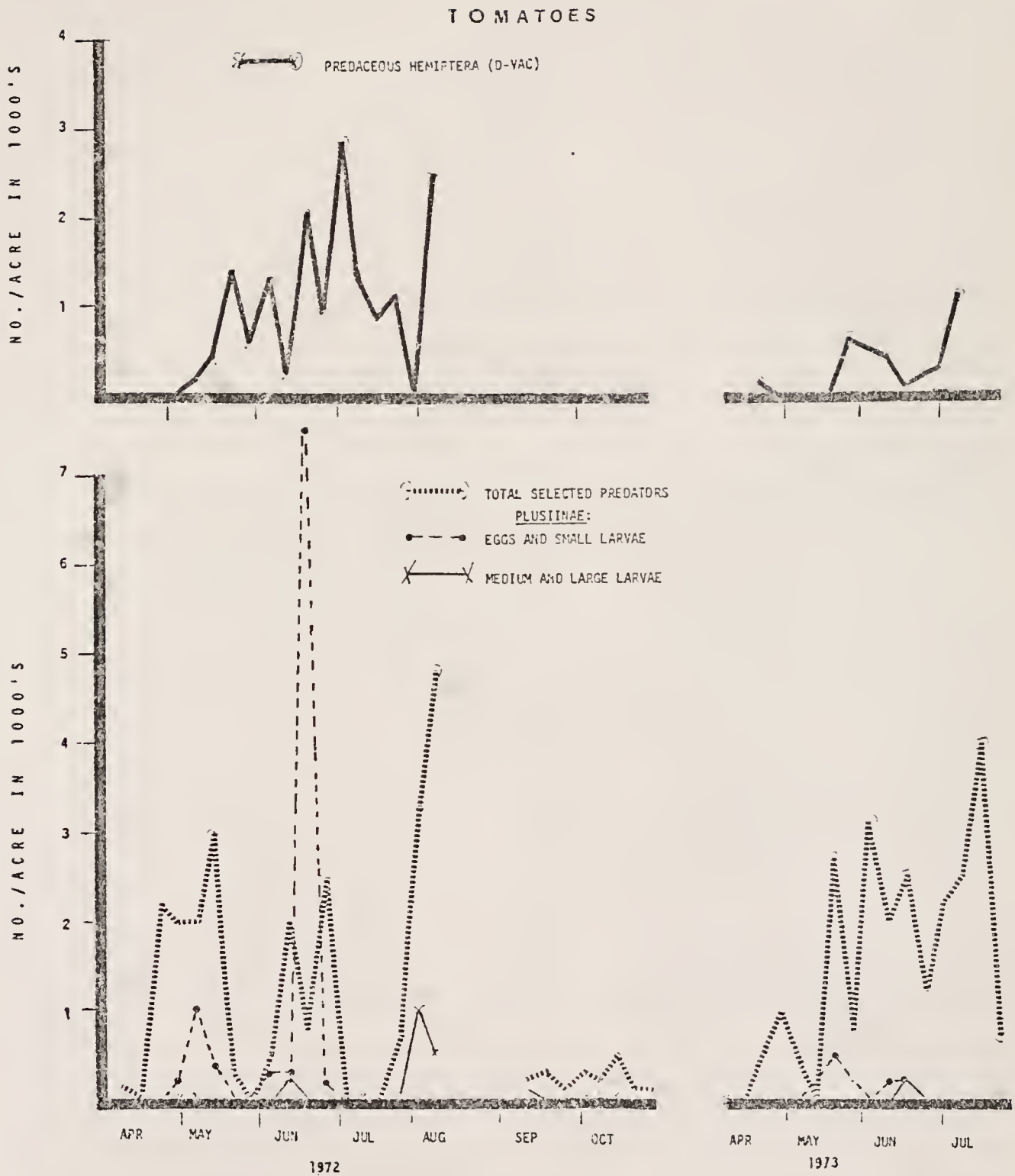

TOMATOES
PREDACEOUS HEMIPTERA (D-VAC)
NO./ACRE IN 1000'S
TOTAL SELECTED PREDATORS
PLUSIINAE:
EGGS AND SMALL LARVAE
MEDIUM AND LARGE LARVAE
APR
MAY
JUN
JUL
AUG
SEP
OCT
1972
1973

Table 29.--Relative and seasonal abundance of selected predaceous arthropods in tomatoes.

Date (week of)	1. Geocoris	2. Nabis	3. Orius	4. Chrysopa	5. Coleomegilla	6. Hippodamia	7. Lady beetle larvae	8. Scymnus	9. Ground beetles	10. Earwigs	11. Other predators	12. Spiders
					Ca. no./acre							
1972												
Apr. 9	0.0		0.0(0.0)	0.0(0.0)	0.0	0.0	0.1				0.0	0.0
16	0.0		0.0(0.1)	0.0(0.0)	0.0	0.0	0.0				0.0	0.0
23	0.0		0.0(0.1)	0.0(0.0)	0.0	0.0	0.6				0.1	1.5
30	0.0		0.0(0.1)	0.0(0.0)	0.0	0.0	1.2				0.0	0.8
May 7	0.0		0.0(0.2)	0.0(0.0)	0.0	0.2	0.3				0.0	1.5
14	0.0		0.0(0.3)	0.0(0.0)	0.0	0.0	0.0				0.0	3.0
21	0.0	None	0.0(1.1)	0.0(0.0)	0.0	0.0	0.0	None	None	None	0.0	0.3
28	0.0	found	0.0(0.2)	0.0(0.0)	0.0	0.0	0.0	found	found	found	0.0	0.0
Jun. 4	0.0		0.0(0.3)	0.0(0.0)	0.0	0.0	0.2				0.0	0.2
11	0.0		0.0(0.0)	0.0(0.0)	0.2	0.5	0.0				0.0	1.3
18	0.0		0.0(0.1)	0.0(0.0)	0.0	0.0	0.8				0.0	0.0
25	0.0		0.0(0.0)	0.0(0.0)	0.0	0.0	2.0				0.2	0.3
Jul. 2-16[b]	0.0		0.0(0.0)	0.0(0.0)	0.0	0.0	0.0				0.0	0.0
23	0.0		0.0(0.0)	0.0(0.1)	0.0	0.0	0.0				0.0	0.7
30	2.0		0.0(0.0)	0.0(0.0)	0.0	0.3	0.3				0.0	0.7
Aug. 6	0.5		0.0(0.0)	0.0(0.0)	0.0	0.0	0.0				0.2	4.2
					No./100 plants (fall, 1972)[a]							
Sep. 10	0.0		0.0	0.0	0.0	0.0	0.0				0.0	14.2
17	0.0		0.0	0.0	0.0	0.0	0.0				0.0	20.0
24	0.0		0.0	0.0	0.0	0.0	0.0				0.0	6.7
Oct. 1	0.0		0.0	0.0	1.6	0.0	0.0				0.0	13.3
8	0.0	None	0.0	0.0	0.0	0.0	0.0	None	None	None	0.0	13.3
15	0.0	found	0.0	0.0	0.0	0.0	0.0	found	found	found	0.0	36.7
22	0.0		0.0	0.0	0.0	0.0	0.0				0.0	6.7
29	0.0		0.0	0.0	0.0	0.0	0.0				0.0	8.3
					Ca. no./acre							
1973												
Apr. 8,15	0.0		0.0(-)	0.0(-)	0.0	0.0	0.0				0.0	0.0
22	0.0		0.0(0.0)	0.0(0.0)	0.0	0.0	0.0				0.0	0.5
29	0.0		0.0(0.0)	0.0(0.0)	0.0	0.0	0.0				0.0	1.0
May 6	0.0		0.0(0.0)	0.0(0.0)	0.0	0.0	0.0				0.0	0.4
13	0.0		0.0(0.0)	0.0(0.0)	0.0	0.0	0.0				0.0	0.0
20	0.0		0.8(0.0)	0.0(0.0)	0.0	0.0	0.0				0.0	1.8
27	0.0	None	0.3(0.6)	0.0(0.0)	0.0	0.2	0.0	None	None	None	0.0	0.5
Jun. 3	0.0	found	0.0(-)	0.0(-)	0.3	0.0	0.2	found	found	found	0.0	1.0
10	0.0		0.0(0.2)	0.0(0.1)	0.0	0.0	0.0				0.0	2.0
17	0.0		0.7(0.0)	0.0(0.0)	0.0	0.0	0.0				0.2	1.7
24	0.0		0.3(0.1)	0.0(0.0)	0.0	0.0	0.0				0.0	0.8
Jul. 1	0.0		0.3(0.0)	0.0(0.0)	0.2	0.0	0.0				0.2	1.5
8	0.2		0.2(0.0)	0.0(0.1)	0.0	0.0	0.0				0.0	2.2
15	0.0		0.0(-)	0.0(-)	0.0	0.0	0.0				0.7	3.3
22	0.2		0.0(-)	0.0(-)	0.0	0.0	0.0				0.0	0.5

Note: The numbered columns represent the following predators: adults and immatures of (1) Geocoris spp. (mostly Geocoris punctipes), (2) Nabis spp., (3) Orius insidiosus, and (4) Chrysopa spp. (mostly C. rufilabris); adults of (5) Coleomegilla maculata and (6) Hippodamia convergens; (7) immatures of the large Coccinellidae; (8) adults of the small Coccinellidae; adults and immatures of (9) Carabidae and (10) Dermaptera; (11) other predaceous insects including adults and immatures of Podisus maculiventris, Calysus spinosus, Reduviidae, and Hemerobiidae, and adults of Notoxus spp.; and (12) adults and immatures of Araneida. None were found if columns are absent. Estimates were generally from weekly inspections of whole plants on ca. 0.003-0.006 acre. However, numbers in parentheses (see 3 and 4) were from D-vac samples of 0.03 acre.

[a]Data were from weekly inspections of 60-100 whole plants.

[b]Samples were taken during the weeks of July 2, 9, and 16.

infrequently. Therefore, (a) factor(s) other than predation (e.g., parasitism) were (was) surely important in maintaining densities of Plusiinae in tomatoes at low levels.

Low densities of soybean loopers in collards were probably due primarily to non-preference of this pest for crucifers. In peanuts and bell peppers, low densities of the soybean looper could have been largely due to both non-preference and predation.

Predators Associated with Tobacco Budworm

The predator complex which occurred in white clover (Table 30) probably prevented higher densities of the tobacco budworm from occurring in April and May. As Lincoln (1972) phrased it: ". . . the first generation of tobacco budworm has a hard time." As was the case with the soybean looper in soybeans, the predaceous arthropods associated with the tobacco budworm occurred at high density levels in white clover, while small, medium and large larvae of Heliothis spp. remained at very low levels (Fig. 21). Major peaks in predator densities occurred in white clover in early May and August, periods when larvae of Heliothis spp. were at their highest density levels. In this spring host of tobacco budworm, G. punctipes, C. maculata, Nabis spp., and spiders were generally abundant throughout the year.

The predaceous arthropod complex which occurred at low densities in tomatoes has been discussed. The total of selected predaceous arthropods did occur at higher densities than the very low densities of Heliothis spp. found in this crop (Fig. 22); however, factors other than predation by predaceous arthropods (i.e., preference for other hosts by the tobacco budworm and high rates of parasitization of eggs of Heliothis spp.) maintained larvae of Heliothis spp. at low density levels in tomatoes.

Table 30.--Relative and seasonal abundance of selected predaceous arthropods in white clover; abundance presented as weekly means of estimated number per acre in 1000's.

Date (week of)	1. Geocoris	2. Nabis	3. Orius	4. Chrysopa	5. Coleomegilla	6. Hippodamia	7. Lady beetle larvae	8. Scymnus	9. Ground beetles	10. Earwigs	11. Other predators	12. Spiders
1972												
Jan. 16[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23[a]	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<0.1
30[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<0.1
Feb. 6[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	<0.1
13[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0
27[a]	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	<0.1	0.0	0.0	0.0	0.0
Mar. 5[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<0.1	0.0	0.0
12[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
26[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apr. 2[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
9	0.0	0.7	0.0(0.0)	0.0(0.0)	9.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0(0.9)	0.0(0.0)	3.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	6.1(0.4)	0.0(0.0)	6.7	0.7	30.3	0.3	0.0	0.0	0.0	9.0
30	1.3	0.0	2.0(2.9)	0.0(0.1)	17.3	0.7	17.3	3.3	0.0	0.0	0.0	3.2
May 7	0.0	2.3	2.0(-)	0.0(-)	16.0	2.7	13.7	1.3	0.0	0.0	0.0	10.0
14	8.7	3.3	0.0(21.0)	0.0(0.1)	21.0	12.8	20.0	10.0	0.0	0.0	0.7	12.0
21	1.3	4.0	0.0(8.5)	0.0(0.0)	7.3	4.7	3.0	0.0	0.0	0.0	0.0	9.3
28	0.0	4.7	0.0(8.3)	0.0(0.0)	0.7	0.0	0.0	0.0	0.0	0.0	0.0	4.6
Jun. 4	1.3	9.3	0.0(2.2)	0.0(0.0)	4.7	0.7	2.7	0.0	0.7	2.6	0.0	5.3
11	2.7	12.0	0.0(0.6)	0.0(0.1)	6.7	3.3	1.3	0.0	0.0	0.0	2.7	0.3
18[a]	5.0	2.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.7	2.0	1.5	0.0	0.0	3.0
25	4.7	8.0	0.0(0.0)	0.0(0.0)	4.7	0.0	8.0	0.0	0.0	0.0	0.7	5.3
Jul. 2	0.0	0.0	0.0(1.1)	0.0(0.1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.7	0.0	0.0(0.4)	0.0(0.0)	6.7	0.0	10.7	0.0	0.0	0.0	0.0	4.0
16	1.7	0.0	0.0(0.7)	0.0(0.0)	3.3	0.0	2.7	0.0	0.3	0.0	0.0	2.0
23	4.7	1.3	0.0(0.9)	0.0(0.1)	14.0	0.0	8.7	0.0	0.0	0.0	0.0	10.7
30	12.0	0.0	0.0(0.1)	0.0(0.0)	5.3	0.0	31.3	0.0	0.0	0.0	0.0	1.3
Aug. 6	16.0	2.0	0.0(0.1)	0.0(0.0)	7.3	0.0	6.0	0.0	0.0	0.0	0.0	11.3
13	27.3	4.0	0.0(0.6)	0.0(0.0)	3.3	0.0	8.0	0.0	0.0	0.0	0.0	10.7
20	18.7	16.0	0.0(0.6)	0.0(0.0)	10.7	4.0	0.0	0.0	2.7	9.3	0.0	18.0
27	3.3	2.7	0.7(0.4)	0.0(0.0)	3.3	0.0	0.2	0.0	0.0	2.7	0.0	12.0
Sep. 3[a]	2.3	0.5	0.3	0.0	0.0	0.0	0.9	0.1	0.1	0.2	0.6	1.5
10[a]	0.5	1.1	1.7	0.0	<0.1	0.0	4.7	0.1	0.1	0.0	0.2	1.8
17	0.0	4.0	0.0(0.3)	0.0(0.1)	1.3	2.7	6.3	0.0	0.7	6.7	0.9	6.7
24[a]	3.4	1.5	0.5	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	5.1
Oct. 1[a]	1.2	0.1	0.1	0.0	0.0	0.0	0.1	0.2	0.0	<0.1	0.1	1.7
8[a]	1.6	0.5	0.0	0.0	<0.1	0.0	0.0	0.2	0.0	<0.1	0.2	2.4
15[a]	1.0	0.0	0.0	0.0	<0.1	<0.1	0.0	0.0	0.0	0.0	0.1	1.1
29[a]	0.8	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	1.6
Nov. 5	0.7	5.0	0.0(0.0)	0.7(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.7
12	0.7	6.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7
19	4.0	4.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.7	0.0	6.7
26[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<0.1
Dec. 3	6.7	3.4	0.0(-)	0.0(-)	0.0	0.0	0.0	2.7	0.0	0.0	0.0	4.6
10	4.0	4.0	0.0(<0.2)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0
17	5.3	2.7	0.0(-)	0.0(-)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3
24	7.3	2.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.7	0.0	0.0	0.0	6.7
31[a]	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	2.8

Table 30.—Continued

Date (week of)	1. Geocoris	2. Nabis	3. Orius	4. Chrysopa	5. Coleomegilla	6. Hippodamia	7. Lady beetle larvae	8. Scymnus	9. Ground beetles	10. Earwigs	11. Other predators	12. Spiders
1973												
Jan. 7	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	1.3	1.3	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0
21	0.0	0.7	0.0(0.1)	0.0(0.0)	0.0	0.0	0.0	0.7	0.0	0.0	0.0	2.0
28	0.7	1.4	0.0(0.1)	0.0(0.0)	0.0	0.0	0.0	0.7	0.0	0.0	0.0	2.7
Feb. 4[a]	<0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1
11	0.0	0.0	0.0(-)	0.0(-)	0.0	0.0	0.0	0.0	0.0	0.0	0.7	4.7
18	0.0	2.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	1.3	0.0	0.0	0.0	3.3
25	2.0	3.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.3	0.0	0.0	0.3	3.3
Mar. 4	1.0	1.4	0.0(0.0)	0.0(0.0)	0.3	0.0	0.0	0.7	0.0	0.0	0.3	1.3
11	2.7	2.0	0.0(0.1)	0.0(0.0)	1.3	0.0	0.0	0.0	0.0	0.0	0.7	5.3
18	0.7	0.7	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.7	2.7
25	0.7	0.7	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.7
Apr. 1	1.3	1.4	0.0(0.0)	0.0(0.0)	0.7	0.0	0.0	0.0	0.0	0.0	1.4	12.0
8	1.3	1.4	0.0(0.0)	0.0(0.0)	0.7	0.0	0.0	0.0	0.0	0.0	2.0	3.3
15	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0
22[a]	0.0	0.1	0.0(0.1)	0.0(0.0)	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.0
29[a]	0.0	0.3	0.0	0.0	0.0	0.0	<0.1	0.0	0.0	0.0	<0.1	0.2
May 5	1.3	4.0	0.0(0.0)	0.0(0.0)	4.0	2.7	5.3	0.0	0.0	0.0	0.0	2.7
13	1.3	3.3	0.0(0.0)	0.0(0.0)	4.0	2.7	2.7	0.0	0.0	0.0	0.7	5.3
20	1.3	12.0	14.6(0.0)	0.0(0.0)	8.7	3.3	11.3	0.0	0.0	0.0	3.3	27.3
27	0.0	2.7	7.3(0.0)	0.0(0.0)	0.0	0.7	2.7	1.3	0.0	0.0	0.0	2.7
Jun. 3[a]	0.2	0.9	2.7	0.0	<0.1	<0.1	0.0	0.0	0.0	0.0	0.1	0.7
10[a]	0.2	0.6	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	<0.1	2.1
17	4.0	6.0	0.0(0.0)	0.0(0.0)	4.0	0.7	2.0	0.0	0.0	0.0	0.7	10.0
24	4.7	5.3	1.3(0.0)	1.4(0.0)	2.7	0.7	2.7	0.7	0.0	0.0	0.0	14.0
Jul. 1	2.6	0.0	1.3(0.0)	0.0(0.0)	0.7	0.7	12.0	0.0	0.0	2.7	3.4	16.0
8[a]	0.5	0.0	0.0	0.0	<0.1	<0.1	1.0	0.0	0.0	0.0	0.2	0.1
15	5.3	0.0	0.0(0.0)	0.0(0.0)	2.7	0.0	0.0	0.0	0.0	1.3	0.7	8.0
22[a]	0.4	0.0	0.0	0.0	0.1	<0.1	0.1	0.0	0.0	0.0	0.7	0.1
29	6.7	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	13.3

Note: The numbered columns represent the following predators: adults and immatures of (1) Geocoris spp. (mostly Geocoris punctipes), (2) Nabis spp., (3) Orius insidiosis, and (4) Chrysopa spp. (mostly C. rufilabris); adults of (5) Coleomegilla maculata and (6) Hippodamia convergens; (7) immatures of the large Coccinellidae; (8) adults of the small Coccinellidae; adults and immatures of (9) Caraboidae and (10) Dermaptera; (11) other predaceous insects including adults and immatures of Podisus maculiventris, Jalysus spinosus, Reduviidae, and Hemerobiidae, and adults of Notoxus spp.; and (12) adults and immatures of Araneida. Estimates were generally from weekly inspections of whole plants on ca. 0.003-0.006 acre. However, numbers in parenthesis were from D-vac samples of 0.03 acre.

[a]Data were from weekly D-vac samples of 0.03 acre.

Fig. 21.--Relative number of small larvae of Heliothis spp., medium plus large larvae of Heliothis spp., total selected predaceous arthropods, large predaceous coccinellids, and selected predaceous Hemiptera in white clover. Predators sampled included adults and immatures of Geocoris spp., Nabis, spp. Orius insidiosus, Podisus maculiventris, Jalysus spinosus, Reduviidae, Chrysopa spp., Micromus spp., predaceous Coccinellidae, Carabidae, Dermaptera, and adults of Notoxus spp., and Araneida. Sampling was by "whole plant" inspections. Many of the Heliothis spp. were tobacco budworm.

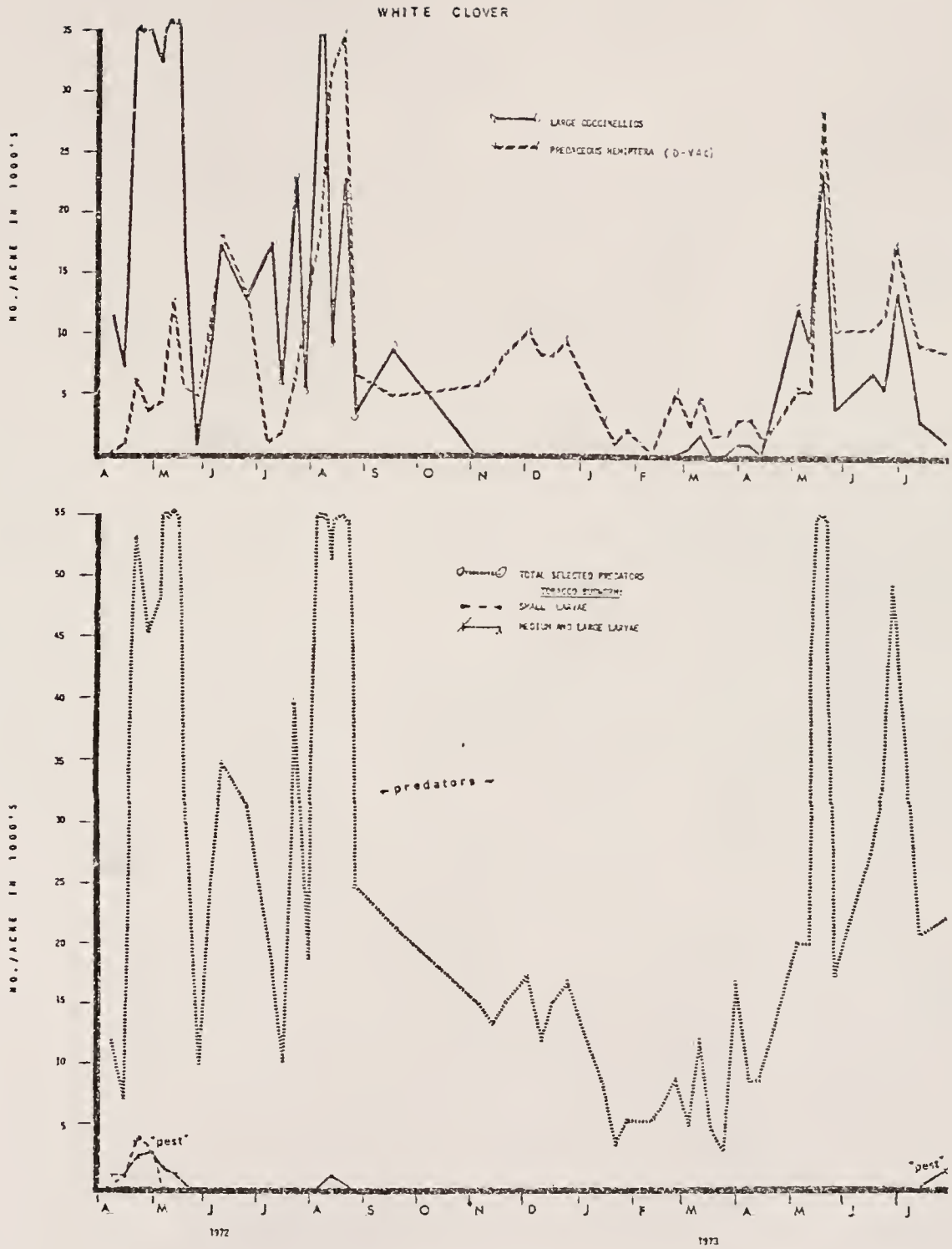
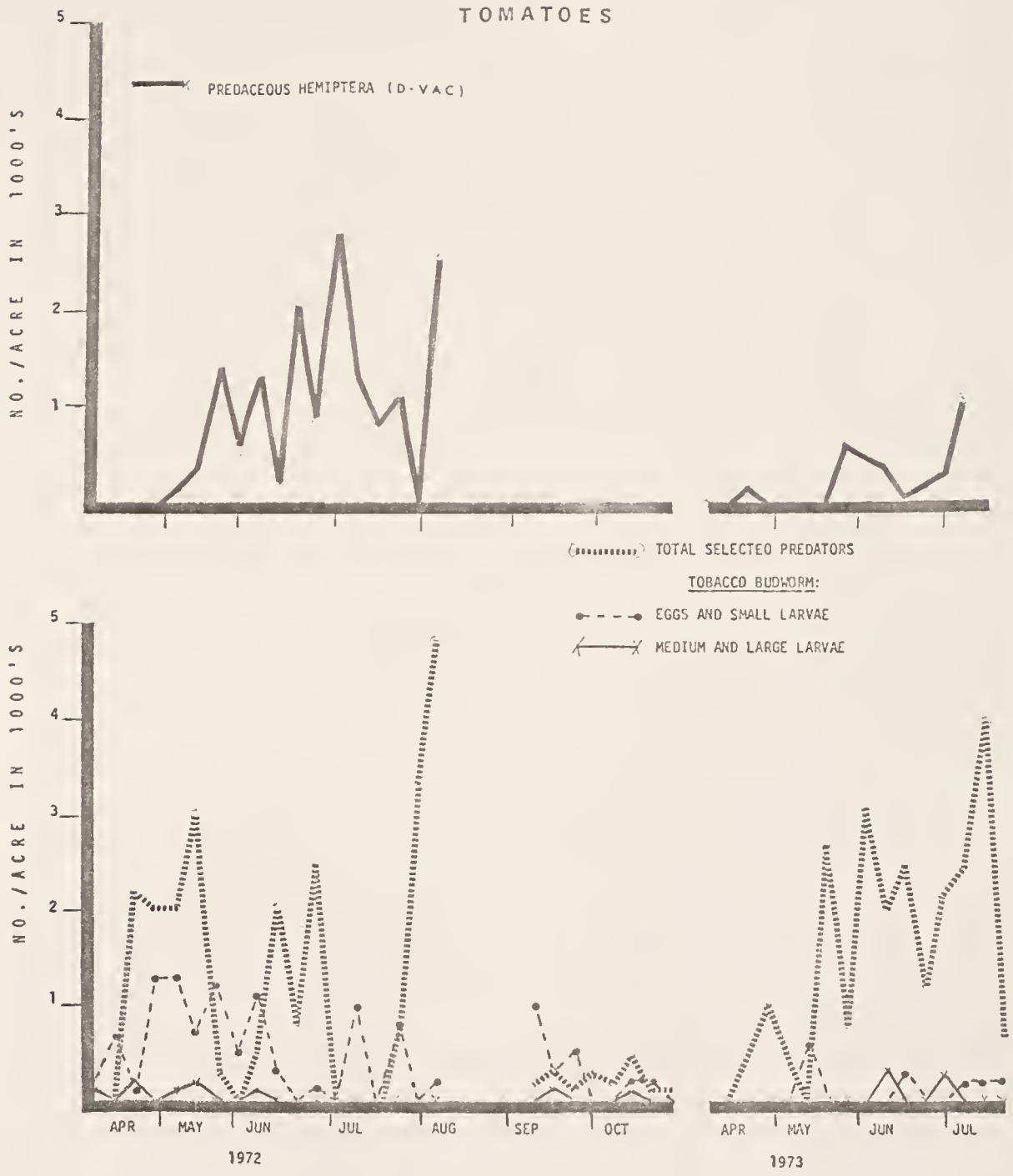

WHITE CLOVER
NO./ACRE IN 1000'S
LARGE COCCINELLIDS
PREDACEOUS HEMIPTERA (D-VAC)
A M J J A S O N D J F M A M J J
TOTAL SELECTED PREDATORS
SMALL LARVAE
PUPAE AND LARGE LARVAE
predators
"pest"
"pest"
1972
1973

Fig. 22.--Relative number of eggs plus small larvae of Heliothis spp., medium plus large larvae of Heliothis spp., total selected predaceous arthropods, and selected predaceous Hemiptera in tomatoes. Predators sampled included adults and immatures of Geocoris spp., Nabis spp. Orius insidiosus, Podisus maculiventris, Jalysus spinosus, Reduviidae, Chrysopa spp., Micromus spp., predaceous Coccinellidae, Carabidae, Dermaptera, and adults of Notoxus spp., and Araneida. Sampling was by "whole plant" inspection and D-vac samples. Many of the Heliothis spp. were tobacco budworm.


TOMATOES
PREDACEOUS HEMIPTERA (D-VAC)
NO./ACRE IN 1000'S
5
4
3
2
1
TOTAL SELECTED PREDATORS
TOBACCO BUDWORM:
EGGS AND SMALL LARVAE
MEDIUM AND LARGE LARVAE
APR
MAY
JUN
JUL
AUG
SEP
OCT
1972
1973

The predaceous arthropod complex in flue-cured (Table 31) and cigar-wrapper tobacco (Table 32) was similar to that found in collards (Table 26). Large coccinellids and spiders were the major predators which occurred in these crops. Coccinellids were found at moderate to low levels in flue-cured tobacco in May and June and in cigar-wrapper tobacco in June and July of 1972. However, few coccinellids were found in flue-cured tobacco in 1973. In contrast to what was found in collards, Hippodamia convergens appeared to occur in flue-cured tobacco at densities similar to C. maculata. Development of high densities of coccinellids in cigar-wrapper tobacco lagged behind that which occurred in flue-cured tobacco because of the cheese-cloth barrier. However, because of higher densities of aphids in cigar-wrapper tobacco, densities of coccinellids eventually increased to higher levels (Table 32) than in flue-cured tobacco (Table 31).

Spiders in tobacco were often estimated at densities similar to those found in collards; however, whole plant inspections (Table 31) and D-vac samples indicated occurrence of this group in tobacco appeared to be erratic. One of the more common species seen in cigar-wrapper tobacco was Oxyopes salticus Hentz; however, most spiders collected in tobacco were not identified.

During some periods G. punctipes (and Nabis spp.) occurred in moderate numbers in flue-cured tobacco (Table 31). A few brown lacewings, small coccinellids, O. insidiosus, D. lineare, and J. spinosus were found in whole plant inspections and D-vac samples, but these predators remained at very low densities in tobacco. Unlike soybeans and collards, few eggs of Chrysopa spp. were found in flue-cured tobacco or cigar-wrapper tobacco.

In both flue-cured (Fig. 23) and cigar-wrapper tobacco (Fig. 24),

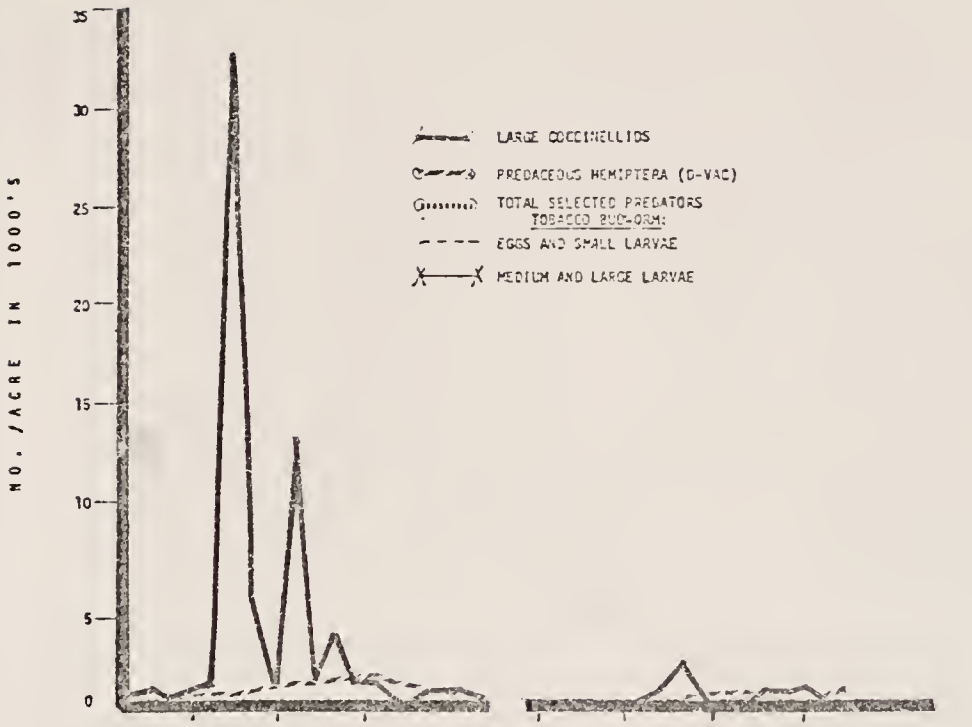
Table 31.--Relative and seasonal abundance of selected predaceous arthropods in flue-cured tobacco; abundance presented as monthly means of estimated number per acre in 1000's.

Date (week of)	1. Geocoris	2. Nabis	3. Orius	4. Chrysopa	5. Coleomegilla	6. Hippodamia	7. Lady beetle larvae	8. Scymnus	9. Ground beetles	10. Earwigs	11. Other predators	12. Spiders
1972												
Apr. 9	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0		0.0	0.0	0.0
16	0.0	0.1	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0		0.0	0.0	1.7
23	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0		0.0	0.0	2.5
30	0.0	0.0	0.0(0.0)	0.0(0.0)	0.2	0.0	0.0	0.0		0.0	0.0	0.0
May 7	0.0	0.0	0.0(0.0)	0.0(0.0)	0.2	0.3	0.1	0.0		0.0	0.0	0.8
14	0.0	0.0	0.0(0.0)	0.0(0.0)	1.8	3.7	27.5	0.0		0.0	0.0	0.7
21	0.3	0.0	0.7(0.0)	0.0(0.0)	0.5	0.0	4.5	0.0		0.0	0.2	1.3
28	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.3	0.0	0.0	None	0.0	0.0	0.0
Jun. 4	0.3	0.2	0.0(0.0)	0.0(0.0)	1.7	4.8	6.7	0.0	found	0.0	0.0	1.3
11	0.2	0.0	0.0(0.0)	0.0(0.0)	0.2	0.5	0.0	0.0		0.0	0.0	0.0
18	0.2	0.0	0.0(0.0)	0.0(0.1)	0.2	3.0	0.0	0.0		0.0	0.0	0.2
25	0.2	0.0	0.0(0.0)	0.0(0.0)	0.3	0.5	0.0	0.0		0.0	0.0	0.5
Jul. 2	0.0	0.0	0.0(0.0)	0.0(0.0)	0.3	0.5	0.0	0.0		0.0	0.0	0.3
9	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0		0.0	0.0	0.0
16	0.0	0.0	0.0(0.0)	0.0(0.1)	0.0	0.0	0.0	0.0		0.0	0.0	0.6
23	0.0	0.0	0.0(0.0)	0.0(0.0)	0.2	0.0	0.0	0.0		0.0	0.8	0.8
30	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.3	0.0	0.0		0.0	0.3	0.3
Aug. 6	0.0	0.0	0.0(0.0)	0.0(0.1)	0.0	0.0	0.0	0.0		0.0	0.0	0.0
1973												
Mar. 25, Apr. 1,8, 15	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0		0.0	0.0	0.1
22,29	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0		0.0	0.0	0.0
May 6	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0		0.0	0.0	0.0
13	0.0	0.0	0.0(-)	0.0(-)	0.0	0.2	0.0	0.0		0.0	0.2	0.0
20	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	1.7	0.3		0.0	0.2	0.0
27,3	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0		0.0	0.0	0.0
Jun. 10	0.0	0.3	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0		0.0	0.3	0.3
17	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.2	0.0		0.0	1.7	0.0
24	0.0	0.0	0.0(0.0)	0.0(0.0)	0.2	0.0	0.0	0.0		0.0	0.2	0.2
Jul. 1	0.3	0.0	0.0(-)	0.0(-)	0.0	0.0	0.5	0.0		0.0	0.0	1.7
8	0.0	0.0	0.0(-)	0.0(-)	0.0	0.0	0.0	0.0		0.3	0.0	3.7
15	0.1	0.0	0.0(0.0)	0.0(0.0)	0.1	0.0	0.0	0.0		0.0	0.0	0.1

Note: The numbered columns represent the following predators: adults and immatures of (1) Geocoris spp. (mostly Geocoris punctipes), (2) Nabis spp., (3) Orius insidiosus, and (4) Chrysopa spp. (mostly C. rufilabris); adults of (5) Coleomegilla maculata and (6) Hippodamia convergens; (7) immatures of the larvae Coccinellidae; (8) adults of the small Coccinellidae; adults and immatures of (9) Carabidae and (10) Dermaptera; (11) other predaceous insects including adults and immatures of Podisus maculiventris, Jalysus spinosus, Reduviidae, and Hemerobiidae, and adults of Notoxus spp.; and (12) adults and immatures of Araneida. None were found if columns are absent. Estimates were generally from weekly inspections of whole plants on ca. 0.003-0.006 acre. However, numbers in parentheses (see 3 and 4) were from D-vac samples of 0.03 acre.

Fig. 23.--Relative number of eggs plus small larvae of tobacco budworm, medium plus large larvae of tobacco budworm, total selected predaceous arthropods, and selected predaceous Hemiptera in flue-cured tobacco. Predators sampled included adults and immatures of Geocoris spp., Nabis spp. Orius insidiosus, Podisus maculiventris, Jalysus spinosus, Reduviidae, Chrysopa spp., Micromus spp., predaceous Coccinellidae, Carabidae, Dermaptera, and adults of Notoxus spp., and Araneida. Sampling was by "whole plant" inspection and D-vac samples.

FLUE-CURED TOBACCO



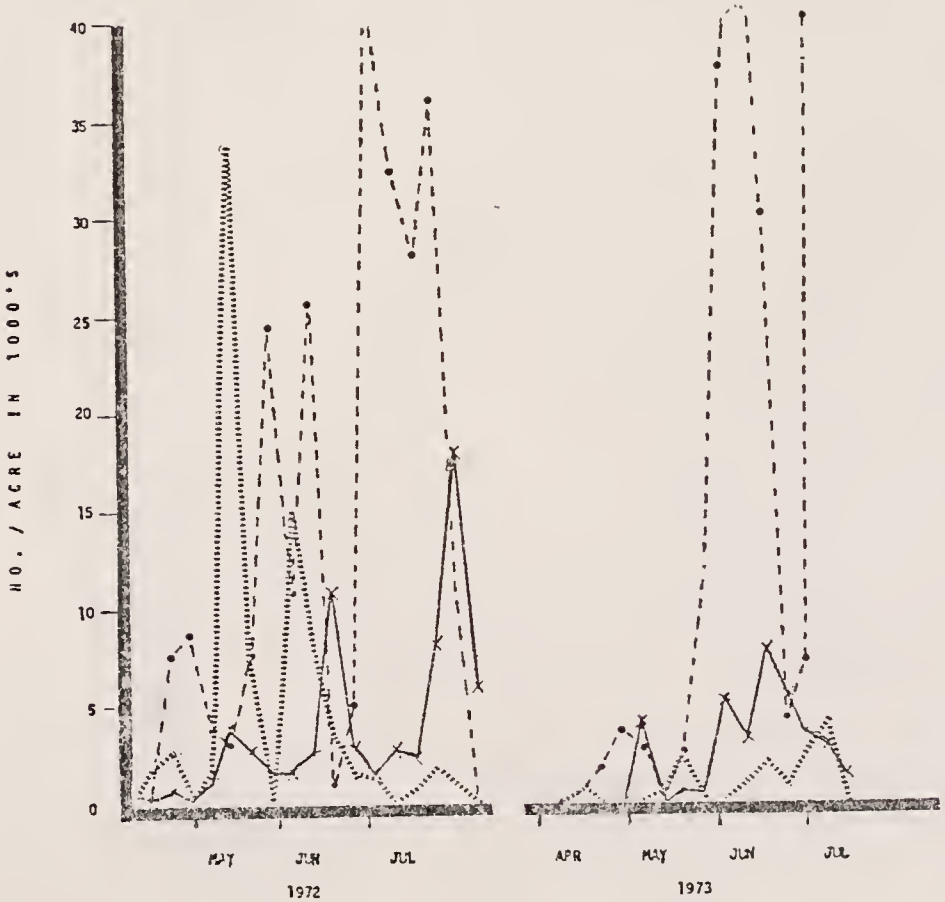
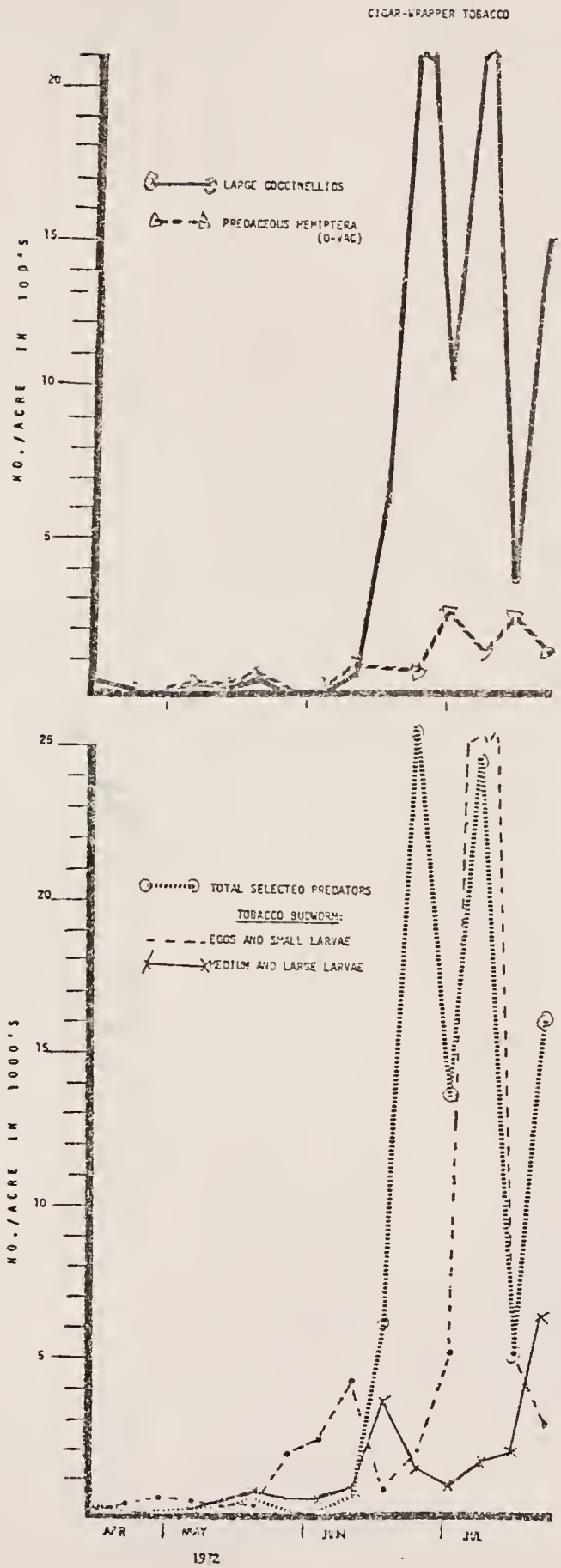


Fig. 24.--Relative number of eggs plus small larvae of tobacco budworm, total selected predaceous arthropods, large predaceous coccinellids, and selected predaceous Hemiptera in cigar-wrapper tobacco. Predators sampled included adults and immatures of Geocoris spp., Nabis spp. Orius insidiosus, Podisus maculiventris, Jalysus spinosus, Reduviidae, Chrysopa spp., Micromus spp., predaceous Coccinellidae, Carabidae, Dermaptera, and adults of Notoxus spp., and Araneida. Sampling was by "whole plant" inspection and D-vac samples.


CIGAR-WRAPPER TOBACCO
NO./ACRE IN 100'S
20
15
10
5
LARGE COCCINELLIDS
PREDACEOUS HEMIPTERA (D-VAC)
NO./ACRE IN 1000'S
25
20
15
10
5
TOTAL SELECTED PREDATORS
TOBACCO BUDWORM:
EGGS AND SMALL LARVAE
MEDIUM AND LARGE LARVAE
APR
MAY
JUN
JUL
1972

densities of tobacco budworms were generally higher than total densities of selected predaceous arthropods. The highest peak of total selected predaceous arthropods occurred in flue-cured tobacco in mid-May of 1972, after a peak of tobacco budworm eggs in late April (Fig. 23). Other peaks in density of total selected predaceous arthropods appeared to follow peaks in tobacco budworm egg densities; however, densities of tobacco budworm larvae were suppressed by a combination of mortality factors including predation. The data indicates that the predator complex in tobacco (Fig. 23 and 24) was definitely not as important a factor in suppressing density levels of tobacco budworms as in other crops.

Diversity of the predaceous arthropods counted was greater in okra than in flue-cured or cigar-wrapper tobacco (Table 32). Coccinellids (primarily C. maculata), G. punctipes, and spiders all occurred at similar densities, and D-vac samples indicated they were generally present at these densities from July-September. Nabis spp. also occurred during this period, but at low densities. In contrast to what was found in flue-cured and cigar-wrapper tobacco, eggs of Chrysopa spp. were found in most whole plant inspection samples and reached densities of up to ca. 13,000 per acre.

In okra, the primary late summer and fall host of tobacco budworms in the 8-acre system, high densities of predaceous arthropods occurred prior to development of similar densities of tobacco budworms in okra (Fig. 25). C. maculata and G. punctipes were at relatively high densities in July and August in this crop (Table 33). However, in October, densities of tobacco budworms did surpass densities estimated for predaceous arthropods.

The relatively high numbers and diversity of predaceous arthropods

Table 32.--Relative and seasonal abundance of selected predaceous arthropods in cigar-wrapper tobacco.

Date (Week of)	1. Geocoris	2. Nabis	3. Orius	4. Chrysopa	5. Coleomegilla	6. Hippodamia	7. Lady beetle larvae	8. Scymnus	9. Ground beetles	10. Earwigs	11. Other predators	12. Spiders
	Ca. no./acre (in 1000's)											
1972												
Apr. 16	0.0	0.0	0.0(0.0)	0.0(0.0)	0.1	0.0	0.0	0.0	0.0		0.0	0.0
23	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0		0.0	1.7
30	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0		0.0	0.5
May 7	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.1	0.0	0.0		0.0	0.1
14	0.0	0.0	0.0(0.1)	0.0(0.0)	0.0	0.1	0.1	0.0	0.0		0.0	0.0
21	0.0	0.0	0.0(0.1)	0.0(0.0)	0.0	0.0	0.3	0.0	0.0		0.0	0.1
28,Jun.4	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	None	0.0	0.0
Jun. 11	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.1	0.4	0.0	0.0	found	0.0	0.0
18	0.0	0.0	0.0(-)	0.0(-)	0.4	3.5	2.3	0.0	0.0		0.0	0.1
25	0.0	0.0	0.0(0.1)	0.0(0.1)	2.2	2.2	20.4	0.0	0.0		0.2	0.5
Jul. 2	1.6	0.0	0.0(0.0)	0.0(0.0)	2.3	5.0	2.9	0.0	0.0		0.0	2.0
9	0.0	0.1	0.0(0.1)	0.0(0.1)	0.7	5.3	16.7	0.1	0.0		0.0	0.0
16	0.7	0.0	0.0(0.1)	0.0(0.1)	0.3	1.8	1.5	0.0	0.0		0.0	0.8
23	0.8	0.0	0.0(0.0)	0.0(0.1)	0.8	6.2	8.1	0.0	0.1		0.1	0.0
	No./100 plants (volunteer tobacco, fall, 1972)[a]											
Sep. 10	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		4.0	0.0
17	26.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
24	0.0	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0		16.7	0.0
Oct. 1	16.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	None	0.0	0.0
8	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	found	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
29	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0

Note: The numbered columns represent the following predators: adults and immatures of (1) Geocoris spp. (mostly Geocoris punctipes), (2) Nabis spp., (3) Orius insidiosus, and (4) Chrysopa spp. (mostly C. rufilabris); adults of (5) Coleomegilla maculata and (6) Hippodamia convergens; (7) immatures of the large Coccinellidae; (8) adults of the small Coccinellidae; adults and immatures of (9) Carabidae and (10) Dermaptera; (11) other predaceous insects including adults and immatures of Podisus maculiventris, Jalysus spinosus, Reduviidae, and Hemerobiidae, and adults of Notoxus spp.; and (12) adults and immatures of Araneida. None were found if columns are absent. Estimates were generally from weekly inspections of whole plants on ca. 0.003-0.006 acre. However, numbers in parentheses (see 3 and 4) were from D-vac samples of 0.03 acre.

[a]Data were from weekly inspections of 60-100 whole plants.

Fig. 25.--Relative number of eggs plus small larvae of tobacco budworm, total selected predaceous arthropods, large predaceous coccinellids, and selected predaceous Hemiptera in okra. Predators sampled included adults and immatures of Geocoris spp., Nabis spp. Orius insidiosus, Podisus maculiventris, Jalysus spinosus, Reduviidae, Chrysopa spp., Micromus spp., predaceous Coccinellidae, Carabidae, Dermaptera, and adults of Notoxus spp., and Araneida. Sampling was by "whole plant" inspections.

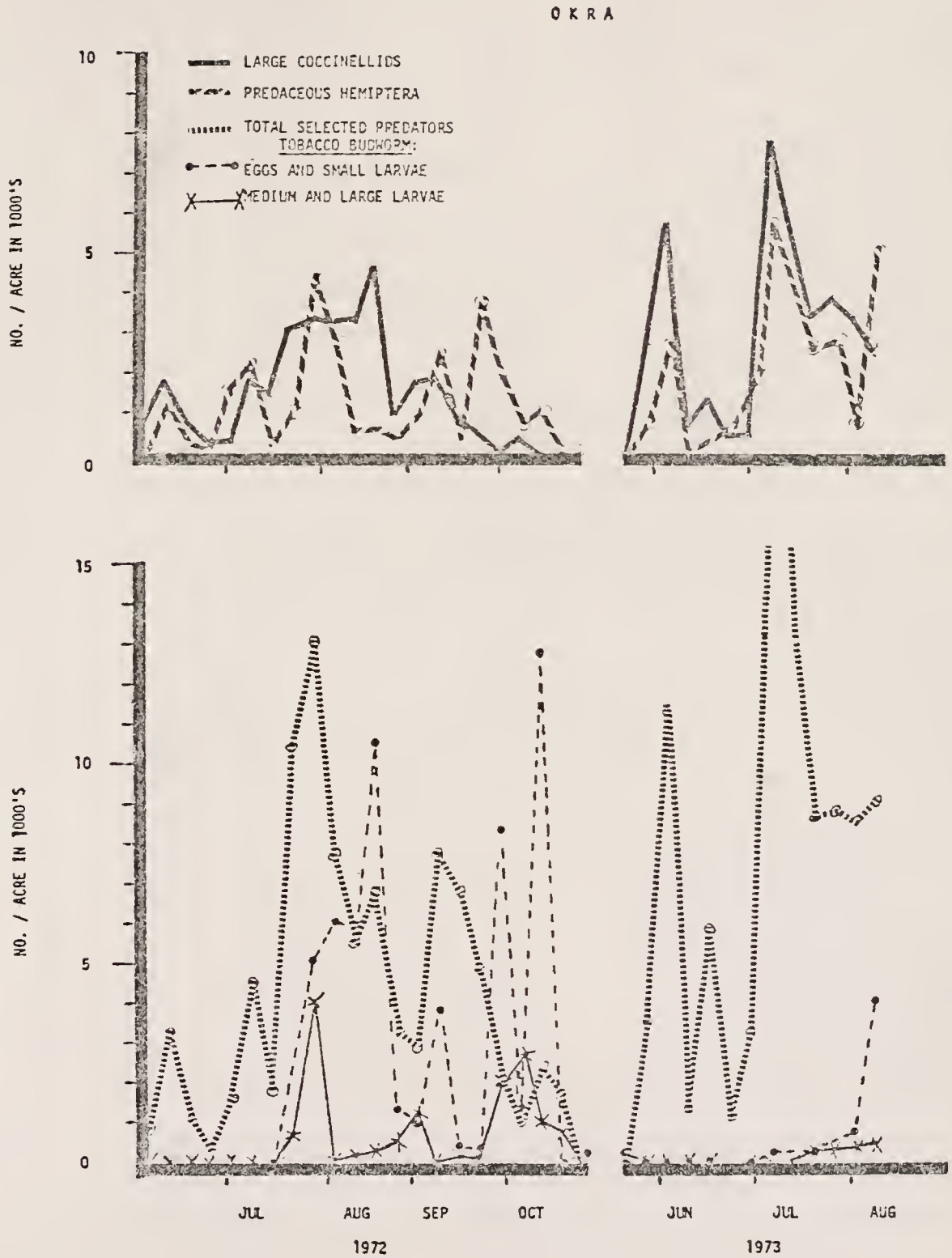

OKRA
LARGE COCCINELLIDS
PREDACEOUS HEMIPTERA
TOTAL SELECTED PREDATORS
TOBACCO BUDWORM:
EGGS AND SMALL LARVAE
MEDIUM AND LARGE LARVAE
NO. / ACRE IN 1000'S
10
5
0
15
10
5
0
JUL
AUG
SEP
OCT
1972
JUN
JUL
AUG
1973

Table 33.--Relative and seasonal abundance of selected predaceous arthropods in okra; abundance presented as weekly means of estimated number per acre in 1000's.

Date (week of		1. Geocoris	2. Nabis	3. Orius	4. Chrysopa	5. Colecmegilla	6. Hippodamia	7. Lady beetle larvae	8. Scymnus	9. Ground beetles	10. Earwigs	11. Other predators	12. Spiders
1972													
Jun.	4	0.0	0.0	0.0(0.0)	0.0(0.0)	0.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0
	11	0.2	0.0	1.0(0.0)	0.0(0.0)	0.3	1.3	0.0	0.0	0.0	0.0	0.0	0.3
	18	0.0	0.0	0.0(0.0)	0.0(0.0)	0.2	0.5	0.0	0.0	0.0	0.0	0.2	0.0
	25	0.0	0.0	0.0(0.0)	0.0(0.2)	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Jul.	2	—	—	— (0.0)	— (0.0)	—	—	—	—	—	—	—	—
	9	2.2	0.0	0.0(0.0)	0.3(0.1)	1.5	0.2	0.0	0.0	0.0	0.0	0.0	0.3
	16	0.0	0.2	0.0(0.0)	0.0(0.0)	1.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0
	23	0.8	0.2	0.0(0.0)	0.3(0.2)	1.2	1.3	0.4	0.1	0.0	0.0	0.0	6.0
	30	4.0	0.3	0.0(0.0)	0.0(0.0)	2.7	0.3	0.3	0.0	0.0	0.0	0.0	5.0
Aug.	6	2.7	0.0	0.0(0.0)	0.0(0.1)	2.0	0.2	1.0	0.0	0.0	0.0	0.2	1.7
	13	0.2	0.2	0.0(0.1)	0.0(0.0)	2.9	0.1	0.3	0.0	0.0	0.3	0.0	1.4
	20	0.2	0.0	0.0(0.0)	0.0(0.1)	1.7	0.0	2.8	0.0	0.0	0.2	0.5	1.3
	27	0.2	0.2	0.0(0.0)	0.0(0.0)	0.5	0.1	0.3	0.0	0.0	0.0	0.0	2.0
Sep.	3	0.8	0.0	0.0(0.1)	0.0(0.0)	1.5	0.1	0.2	0.0	0.0	0.0	0.2	0.2
	10	2.2	0.0	0.0(0.1)	0.0(0.0)	0.3	0.0	1.3	0.0	0.0	0.0	0.3	3.5
	17	0.3	0.0	0.0(0.1)	0.0(0.0)	0.7	0.0	0.0	0.0	0.0	0.2	0.0	0.5
	24	0.0	1.0	0.0(0.0)	0.0(0.0)	0.3	0.2	0.0	0.0	0.0	0.0	2.7	0.7
Oct.	1	1.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
	8	0.7	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
	15	1.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
	22	0.0	0.0	0.0(0.1)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7
	29	0.0	0.0	0.0(0.0)	0.0(0.1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1973													
May	20	0.0	0.0	0.0(-)	0.0(-)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	27	0.7	0.2	0.0(0.1)	0.0(0.0)	0.0	2.2	0.5	0.0	0.0	0.0	0.0	0.0
Jun.	3	1.3	0.3	1.0(0.0)	0.0(0.0)	1.3	3.3	1.0	0.0	0.0	0.0	0.0	3.0
	10	0.0	0.0	0.0(0.0)	0.0(0.0)	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.7
	17	0.2	0.2	0.0(0.1)	0.0(0.0)	0.3	1.0	0.0	0.0	0.3	0.0	1.3	2.5
	24[a]	0.2	0.1	0.0(0.1)	0.0(0.0)	0.0	0.1	0.2	0.0	0.0	0.0	0.2	0.2
Jul.	1	0.9	0.0	0.8(0.2)	0.1(0.0)	0.0	0.2	0.2	0.0	0.0	0.0	0.1	0.4
	8	4.2	0.0	0.8(0.0)	0.7(0.0)	2.5	1.8	3.3	0.0	0.0	0.0	0.7	4.3
	22	1.9	0.0	0.5(0.0)	0.2(0.0)	2.2	0.0	1.2	0.0	0.1	0.8	0.1	1.4
	29	2.8	0.0	0.0(-)	0.0(-)	3.0	0.2	0.7	0.0	0.0	0.0	0.0	2.0
Aug.	5	0.0	0.0	0.0(-)	0.0(-)	0.8	0.2	2.3	3.3	0.0	0.5	0.7	0.7
	12	3.0	0.0	0.5(0.0)	0.5(0.0)	1.5	0.0	1.0	0.0	0.0	0.5	1.5	0.5

Note: The numbered columns represent the following predators: adults and immatures of (1) Geocoris spp. (mostly Geocoris punctipes), (2) Nabis spp., (3) Orius insidiosus, and (4) Chrysopa spp. (mostly C. rufilabris); adults of (5) Coleomegilla maculata and (6) Hippodania convergens; (7) immatures of the large Coccinellidae; (8) adults of the small Coccinellidae; adults and immatures of (9) Carabidae and (10) Dermaptem; (11) other predaceous insects including adults and immatures of Podisus maculiventris, Jalysus spinosus, Reduviidae, and Hemerobiidae, and adults of Notoxus spp.; and (12) adults and immatures of Araneida. Estimates were generally from weekly inspections of whole plants on ca. 0.003-0.006 acre. However, those in parenthesis (see 3 and 4) were from D-vac samples of 0.03 acre.

[a]Data were from weekly D-vac samples of 0.03 acre.

found in okra, in combination with the egg parasitism which occurred in this crop may have prevented higher densities of Heliothis spp. from occurring in this crop and could explain why few specimens of larvae of this pest were found in okra in 1973 (Fig. 25). However, in 1972 the tremendous influx of tobacco budworms from tobacco was probably more than the predator complex in okra could suppress to low densities.

Summary

Data from whole plant inspections and supporting data from D-vac and sweep-net samples, indicate Geocoris punctipes, Nabis spp., Coleomegilla maculata, Hippodamia convergens, and spiders were 5 of the most abundant groups of predaceous arthropods associated with the cabbage looper, soybean looper, and tobacco budworm in the 8-acre cropping system. The 2 Hemiptera and the spiders were at relatively high densities throughout the year, whereas, the coccinellids were rarely found in the fall and winter months.

White clover was the most important source of predaceous arthropods in the system. However, a number of other crops, such as rye, wheat, sweet corn, field corn, millet, soybeans, and sorghum were also key contributors to the predaceous arthropod complex because they were important in sustaining substantial levels of some predators and/or they allowed them to increase to relatively high densities. Some crops, e.g. tomatoes, had very low densities of predaceous arthropods, but it was usually those crops with "intermediate" predator densities which possessed the highest densities of cabbage looper (e.g. collards) and tobacco budworm (e.g. flue-cured tobacco).

The cabbage looper population numbers were not suppressed to low

densities in cabbage and collards, and the increase of the total selected predaceous arthropods and of coccinellids, the major predator group associated with cabbage looper, generally lagged behind increases of eggs and small larvae of the cabbage looper. The reduction of densities of larger larvae from those of eggs and small larvae was probably largely due to mortality factors other than predation.

In contrast, the high densities of the relatively diverse complex of predaceous arthropods may have been a major factor in keeping densities of the soybean looper at low levels. G. punctipes and Nabis sp. were the major predaceous arthropods in soybeans which were associated with the soybean looper.

G. punctipes, Nabis spp., and other predaceous arthropods were not abundant in tomatoes. But a combination of mortality factors, including egg parasitism, and predation, probably helped to maintain low densities of Plusiinae (and Heliothis spp.) in this crop.

The tobacco budworm was probably kept at low densities in white clover by the high densities of predaceous arthropod populations, including those of coccinellids, G. punctipes, and Nabis spp. However, in tobacco, densities of the selected predaceous arthropods, including coccinellids, the major group in these crops, were not able to suppress densities of the tobacco budworm to low levels. Although tobacco budworm larvae were probably above an economic infestation threshold in okra, the combination of egg parasitism and predation by the diverse predaceous arthropod complex helped to maintain them at lower densities than that occurring in tobacco.

SECTION V

RELEASES OF SUPPLEMENTAL *Trichogramma pretiosum* AND *Chrysopa carnea*

Investigations reported in Sections III and IV indicated that *Trichogramma* spp., *Chrysopa* spp., and other natural enemies, are important suppressants acting on population densities of the cabbage looper, soybean looper, and tobacco budworm. However, regulation of population densities of cabbage looper and tobacco budworm, in particular, is often at higher levels than can (or will) be tolerated in most cropping systems (Section II). Therefore, some types of artificial suppression techniques would normally need to be employed to keep these pests below "economic" injury levels.

Thus, the cabbage looper, soybean looper, and tobacco budworm are vulnerable to suppression by natural enemies, including *Trichogramma* spp. and *Chrysopa* spp., but native populations of these entomophages need to be augmented to satisfy man's demand for quality agricultural products. Manipulation of natural enemies of pest species is one promising way to achieve additional suppression of some crop pests (DeBach and Hagen 1964; Wilson 1966; Ridgway 1969, 1972; Ridgway *et al.* 1974; DeBach 1974). Supplemental releases of natural enemies, in particular, have shown considerable potential for suppressing some pests (Doutt and Hagen 1949, 1950; Huffaker and Kennet 1956; Ridgway and Jones 1968, 1969; Lingren 1970; Stinner *et al.* 1974b).

A large portion of the research efforts into suppression of pests by supplemental releases of natural enemies, has been concentrated on *Trichogramma* spp. (DeBach and Hagen 1964). Research and utilization of

Trichogramma spp. for suppressing several pests has advanced substantially in Mexico (DeBach 1974) and the Soviet Union (Dysert 1973; DeBach 1974). "The Soviet Union leads the world in research and application of mass releases of species of Trichogramma" (DeBach 1974). According to DeBach (1974), ca. 6 million acres received releases of Trichogramma spp. in the Soviet Union, at a cost of a few cents per acre, in 1968. Research on Trichogramma spp. has also advanced substantially in the U.S. in recent years (Ridgway et al. 1974), and these egg parasitoids are available commercially in this country (DeBach 1974).

Similarly, Chrysopa spp. have been produced commercially in the U.S. at Rincon-Vitova Insectories, Inc., Rialto, CA, for a number of years at rates of more than 50 million per year (Ridgway et al. 1974). In their studies on this predaceous Neuroptera species, Ridgway and Jones (1969) demonstrated that releases of Chrysopa carnea could be used to effectively suppress Heliothis spp. below an economic threshold in Texas cotton.

The objective of the tests presented in this section was to determine if supplemental releases of Trichogramma pretiosum and C. carnea, at rates similar to those which gave substantial suppression in Texas cotton (Stinner et al. 1974b; Ridgway and Jones 1969), would suppress high numbers of Plusiinae (cabbage loopers and soybean loopers) and Heliothis spp. (especially tobacco budworms) in tobacco, soybeans, and several other crops commonly grown in northern Florida.

Literature Review

Trichogramma pretiosum

Trichogramma spp. have been mass-reared successfully for research and commercial purposes for a number of years (DeBach and Hagen 1964; Ridgway

et al. 1974). Recently substantial advances have been made in developing techniques for quality control in the production of these egg parasitoids (Stinner et al. 1974d), in methods for manipulating them in field releases (Lewis et al. 1975; Stinner et al. 1974c), and in means of rearing them on an artificial diet (Hoffman et al. 1975). Lewis et al. (1975) have recently shown that blanket coverage of crops with kairomones of moths (corn earworm) can substantially increase parasitization of natural and artificially applied Lepidoptera eggs by Trichogramma spp., including T. pretiosum.

Some encouraging results have recently been obtained after supplemental releases of Trichogramma spp. on lepidopterous pests, in several crops (Ridgway et al. 1974). In California, releases of a uniparental strain of Trichogramma spp. at a rate of ca. 32,800 per week/acre in tomatoes, resulted in a substantial increase in parasitization of eggs of the cabbage looper (Oatman and Platner 1971). Parasitism averaged 59% in the release field, with a range of 28 to 100%, compared to a mean of 42% in a control field, with a range of 0 to 100%. Parasitism in the control was due to native T. pretiosum.

Oatman and Platner also found that releases of T. pretiosum at a rate of ca. 40,200 per week/acre yielded 39% parasitism with a range of 16 to 100% as compared to a 10% in a control field with a range of 0 to 67%. They concluded that by using twice-weekly releases of T. pretiosum for a total of ca. 465,000 per acre during June and July, the cabbage looper and the corn earworm could be suppressed to tolerable levels in southern California tomatoes.

In contrast, Parker and Pinnell (1972) found 2 strains of T. pretiosum were ineffective in controlling the cabbage looper in Missouri cabbage.

However, releases of another species, Trichogramma evanescens Westwood, resulted in 68 to 90% parasitization of cabbage looper eggs. All 3 strains parasitized a high percentage of cabbage looper eggs in the laboratory. Other studies suggest that neither T. pretiosum (Fye and Larsen 1969) nor T. evanscens (Schmidt 1970) are well-adapted control agents for the cabbage looper. Ashley et al. (1974) found that his strain(s) of T. pretiosum preferred corn earworm to cabbage looper eggs.

Tobacco budworms and corn earworms were suppressed substantially in Texas cotton after high rates of egg parasitism were achieved through supplemental releases of T. pretiosum (Lingren 1970; Stinner et al. 1974b). Subsequent research has indicated that aerial releases of this egg parasitoid are also effective and that this parasitoid can be used to suppress Heliothis spp. on large acreages of cotton (Ridgway et al. 1973).

In their review of research on supplemental releases of parasitoids and predators, Ridgway et al. (1974) pointed out that releases of Trichogramma sp. at rates of more than 100,000 per acre at 2-3 day intervals may be necessary for effective suppression of Heliothis spp. Stinner et al. (1974b) did obtain a 66-80% reduction in larvae of Heliothis spp. with properly-timed releases of 77,500-387,500 adults of T. pretiosum per acre/release.

Chrysopa carnea

Ridgway and Kinzer (1974) reviewed the status of Chrysopa spp. as predators of crop pests. C. carnea is abundant in many areas of the U.S. (Burke and Martin 1956; Whitcomb and Bell 1964; van den Bosch and Hagen 1966; Brown and Bickley 1963; Tauber 1974) and is tolerant to several insecticides (Ahmed et al. 1954; Ahmed 1955; Bartlett 1964; Lingren and Ridgway 1967; Ridgway et al. 1967).

Lingren et al. (1968b) released 420,000 larvae of C. carnea per acre in field cages which reduced the population of developing tobacco budworm

eggs up to 76% and the population of developing tobacco budworm larvae up to 96%. Distribution of 800,000 C. carnea eggs per acre in field cages resulted in densities of 15,000 tobacco budworm larvae/acre compared with >60,000/acre in control cages (Ridgway and Jones 1968). Release of 400,000 C. carnea larvae per acre caused a similar reduction of tobacco budworm larvae.

When C. carnea were released after stem application of monocrotophos (which probably killed most aphids, an alternate host for the C. carnea), tobacco budworms were reduced to only 266 larvae per acre (Ridgway and Jones 1969). Field releases of 92,000 C. carnea per acre and 200,000/acre a week later, reduced a peak population of larvae of Heliothis spp. by 96%.

Generally releases of eggs and adults of C. carnea have resulted in only limited success in suppressing Heliothis spp. (Ridgway and Kinzer 1974). However, releases of 10,000 larvae per acre usually results in some reduction of Heliothis spp., and high levels of reduction are obtained with releases of 100,000 larvae/acre (Ridgway and Kinzer 1974; Ridgway et al. 1973, 1974). Research is progressing towards less expensive rearing techniques (Vanderzant 1969; Anonymous 1971b; Ridgway and Kinzer 1974; Ridgway et al. 1974) and improved application methods (e.g. aerial application of C. carnea mixed with sawdust) (Anonymous 1972b; Ridgway and Kinzer 1974).

Methods and Materials

Trichogramma pretiosum

T. pretiosum were released against the cabbage looper, soybean looper, and tobacco budworm on the crops of the 1-acre cigar-wrapper tobacco shade discussed in Section I. Releases of cabbage loopers, soybean loopers, and tobacco budworms were also made in order to establish pest populations in the 1-acre shade (Section II).

T. pretiosum were shipped from the Cotton Insects Res. Laboratory, Agr. Res. Serv., USDA, College Station, TX, in the larval stage in Angoumois grain moth (Sitotroga cerealella (Olivier)) eggs glued to heavy-weight black construction paper (4.2 x 10.0 in.). After reaching Quincy, FL, T. pretiosum were held at ca. 27°C until the 8th day of their development. The cards were then cut into 60 equal portions, placed in 4-dr plastic cups, and stored in a dark room at a temperature of 20±1°C. When T. pretiosum began emerging 11-12 days after the host eggs were stung, they were taken from the cool room, held at ca. 27°C, and released within 3 hours.

I sampled the cards possessing the developing T. pretiosum with a No. 7 cork borer (1/380 of a card) in 2 positions determined to be representative sampling areas (Stinner et al. 1974c). T. pretiosum emerging from these samples, and those emerging in 4 cups not used in each field release, were used to estimate the number of T. pretiosum released per acre. Other T. pretiosum shipped from College Station and emerging within 1 day of released-T. pretiosum emergence were used to estimate sex ratio. Twelve samples of 100 individuals were sexed for each release date.

T. pretiosum were released onto the foliage of the 7 crops, at 1100 to 1200 hours on the release dates, at a mean rate of ca. 378,000 per acre/release at 3 day intervals beginning August 17 and ending August 23. Sex ratio of these released T. pretiosum averaged 1.6 (♀/♂). Releases for August 17 and 23 were made on odd numbered rows and on August 20 on even numbered rows, at 8 positions (1 cup per position) within each row (ca. 22 ft apart). In tobacco and cabbage, numbers of released T. pretiosum were actually concentrated somewhat since they were placed on the nearest foliage of the crop when the predetermined release areas were void of vegetation.

In order to determine parasitization rates, lepidopterous eggs in the field were collected during whole plant inspections and placed in tape-made-cells as discussed previously (Section I). They were brought into laboratory and allowed to develop at ca. 27°C.

Samples of the egg parasitoids were taken, and sent to L. R. Ertle, Agr. Res. Serv., USDA, Newark, DE, for identification. Also, sex ratios and number of Trichogramma spp. emerging per egg were estimated from 40 parasitized eggs of Heliothis spp. and 100 parasitized Plusiinae eggs selected at random from those eggs collected during the release period.

Sampling methods used to determine the number of eggs and larvae of Plusiinae and Heliothis spp. per acre in crops of the 1-acre shade were discussed in Section I. Samples for numbers of and parasitization of immature Lepidoptera prior to the 1st T. pretiosum release were taken on August 4, 11, and 16. During the T. pretiosum release period from August 17 to 25, samples were taken on all dates except August 21 and 22. After releases were terminated samples were taken on 11 dates from August 27-September 22.

Eggs and many larvae counted and collected in the 1-acre shade were not identified to species. This was discussed in Section I. However, from identifications of many collected larvae and the relationship of moth releases and egg peaks occurring in the 1-acre shade, it is possible to determine with some accuracy which species of Plusiinae or Heliothis spp. was (were) attacked and suppressed by T. pretiosum releases at various times in the various crops.

Almost all of the Plusiinae larvae collected in collards, cabbage, and bush beans, plus the only one collected on cigar-wrapper tobacco were cabbage looper. Prior to soybean looper releases most larvae

collected in soybeans were cabbage loopers; afterwards, most were soybean looper. The only Plusiinae larvae identified from tomatoes was a soybean looper; also, it was collected prior to soybean looper releases. However, peaks of Plusiinae eggs in tomatoes and bell peppers corresponded to the respective release periods for cabbage loopers and soybean loopers (Fig. 26).

All of the tobacco budworm larvae identified were from cigar-wrapper tobacco, tomatoes, and bell peppers. Most of the larvae of Heliothis spp. collected in cigar-wrapper tobacco were tobacco budworm and 1 of 3 collected in bell peppers was a tobacco budworm. Only 2 of 63 collected in tomatoes and none of 5 collected in soybeans were "positively" identified as tobacco budworms; however, many of the peaks of eggs of Heliothis spp. detected in these 2 crops (Fig. 27) appeared to correspond with tobacco budworm moth releases.

In an additional experiment on suppression of the soybean looper by T. pretiosum, 4 releases of T. pretiosum, each of 588,000-650,000 per acre and having ca. 1.7♀/♂, were made in a 1.3-acre soybean field on August 23, 26, 30, and September 11. Parasitoids used in the first 3 releases were handled similar to those released in the 1-acre shade and were released 10-12 days from the date the host eggs were stung. However, those used for the final release had began emerging for 24-48 hr before they were released at 13-14 days after the "sting date."

Sampling in the 1.3 acre field was limited and number of soybean looper, or other potential hosts, per acre was not estimated. Parasitization rates were monitored primarily by collecting eggs oviposited by laboratory-reared soybean loopers and/or velvetbean caterpillars caged in 4 small areas (ca. 10 ft^2 each) scattered diagonally across the rectangular

field. Collections of eggs oviposited by caged moths were made on August 24, 30, September 2, 6, 7, 13, and 20, and collections of eggs oviposited by wild moths were made on September 14, 17, and 24. No soybean looper eggs were collected prior to T. pretiosum releases, 140 soybean looper eggs were collected 1 day after the 1st release, 84 soybean looper eggs were collected 4 days after the 2nd release, and a total of 117 soybean looper eggs were collected 3, 7, and 8 days after the 3rd release. Only 4 soybean looper eggs were collected 2 and 3 days after the 4th release of T. pretiosum, but an additional 20 eggs were collected 6-13 days after this release.

Chrysopa carnea

Larvae of C. carnea were also tested as potential suppressive agents against cabbage loopers, soybean loopers, and tobacco budworms in crops of the same 1-acre shade in which the T. pretiosum were released. C. carnea were shipped from Cotton Insects Res. Laboratory, Agr. Res. Serv., USDA, College Station, TX, in three 3-gal cylindrical cartons, as eggs mixed with sawdust and previously frozen Angoumois grain moth eggs. On arrival at Quincy, C. carnea developed at ca. 27°C. I estimated number of C. carnea released by counting two 1/2-pt aliquots from each 3-gal carton.

I released larvae of C. carnea on half of each crop (2 and 1/2 rows in bush beans and cigar-wrapper tobacco, and 5 rows in the rest of the crops) in the 1-acre shade. The first 2 releases (of ca. 240,000 larvae per acre and ca. 210,000 larvae/acre) were made on August 20 and 27. The 3rd release (ca. 130,000 larvae per acre) was made on 2 separate days; 1/2 of the C. carnea-containing sawdust was spread over the release plots on September 4 and the rest was dispensed on September 5. On September 16 the release plots in soybeans and collards were again treated at a rate of

ca. 50,000 per acre. Larvae of C. carnea released on August 20 and 27 were ca. 2 days old (or 2 days from eclosion); those released on September 4 and 5 were ca. 3-5 days old; and those on September 16 were ca. 7 days old.

Sawdust containing the C. carnea was distributed mostly by hand, from 1-gal cartons, evenly onto the plant foliage late in the afternoon. (However, during the 1st release, bush beans, cigar-wrapper tobacco, soybeans, and collards were treated by using a back-pack Chrysopa distributor described by Kinzer et al. (1971) which became inoperable.) Three-tenths-gal of the mixture was dispensed on each 200 ft of row.

Numbers of adults and immatures of Chrysopa spp., and eggs and larvae of Plusiinae and Heliothis spp., in release and control plots of crops of the shade, were estimated from the whole plant inspections (Section I) in 3 to five 5-20 row-ft sections of crops on each sampling date. Samples were taken on the same dates detailed for determining the effect of T. pretiosum releases. Weekly means were calculated and plotted for estimates of eggs and larvae of Plusiinae and Heliothis spp. in release and control plots. Samples were taken in all crops during the weeks of August 1, 8, and 15 prior to C. carnea releases, and every week through the week of September 19 after releases were begun.

In addition to the estimates previously discussed, on August 28, the day after the 2nd release, numbers of larvae of Chrysopa spp. in release plots were estimated by taking two 10-ft sections in the first 2 release rows of each crop and counting only larvae of Chrysopa spp.

Also, 100-row-ft in the C. carnea release area, and in the non-release area of each crop, was sampled with a D-vac machine on August 17 prior to the 1st release of C. carnea and on August 19, 25, September 1, 9, 16, and

23 after releases were begun (Section I). The samples were stored in a freezer until Chrysopa spp. were searched for and counted under magnification.

A rating system for foliage damage similar to that used by Greene et al. (1969) was used on crops of the 1-acre tobacco shade. The scale ranged from 1 to 6 as follows: 1) no apparent insect feedings, 2) 0-1% leaf area eaten, 3) 2-5% leaf area eaten, 4) 6-10% leaf area eaten, 5) 11-30% leaf area eaten, and 6) over 30% of the leaf area eaten. (Fifty plants were rated in each release and control plot on each sample date.) Yield of fruit in C. carnea release and control plots and fruit damage by larvae of Heliothis spp., was estimated from 5 to 10 ten-ft samples per plot/sample date for all crops except cigar-wrapper tobacco, collards, and cabbage. Means for the foliage and fruit damage, and yields, were tested by using a student's "t" test.

In an additional test in an area separate from the 1-acre shade, about two hundred 4-to 6-day-old larvae were released in 3-row-ft sections of soybeans containing 50 eggs of soybean looper which had been cemented to the lower leaf surface with egg albumin. This test was replicated 4 times and means were tested by using a student's "t" test.

Another test was conducted to determine capability of the larvae of C. carnea shipped from College Station for consuming eggs and larvae of cabbage loopers, soybean loopers, and tobacco budworms. Eggs of the cabbage looper (20), soybean looper (67-109), and tobacco budworm (20) were each offered separately to 5-15 individual larvae of C. carnea in 1-dr glass vials. Ten lst-instar larvae of the cabbage looper and the tobacco budworm were each presented separately to 10 individual larvae of C. carnea in 4-dr clear, plastic cups containing cabbage looper larval

diet. C. carnea larvae were held at ca. 27°C for 24-48 hr. Number of noctuid eggs and larvae consumed, and mortality of the C. carnea larvae was recorded.

Results and Discussion

Trichogramma pretiosum

There was a marked increase in egg parasitization in most crops after release of T. pretiosum (Fig. 26 and 27, Table 34). Pre-release records taken from August 4-16 indicated 1.6 and 4.9% parasitization of Plusiinae and Heliothis spp. eggs, respectively (Table 34). Although not shown in tabular form, at 1 day before release, parasitization of eggs by Trichogramma spp. was 1.6% for Plusiinae and 5.7% for Heliothis spp. At 1 day after release, parasitization had increased to 50.3% for Plusiinae and 40% for Heliothis spp. Parasitism during and until 2 days after the 3 releases was 54 and 43% for Plusiinae and Heliothis spp., respectively (Table 34), and it remained relatively high on some crops until termination of the experiment 1 month later.

The released parasitoids were apparently able to complete generation cycles on those crops that had a suitable host habitat and adequate numbers of host eggs (Fig. 26 and 27). The cycling was evident on eggs of Plusiinae on collards, cabbage, tomatoes, soybeans, and bell peppers, and on eggs of Heliothis spp. on tomatoes.

Cabbage looper

In collards densities of cabbage looper larvae remained well below densities of eggs until mid-September (Fig. 26a). Highest numbers of eggs were found on August 17, 27, and September 6, when they reached densities of ca. 41,150, of 63,390, and of 60,050 per acre, respectively. Peak

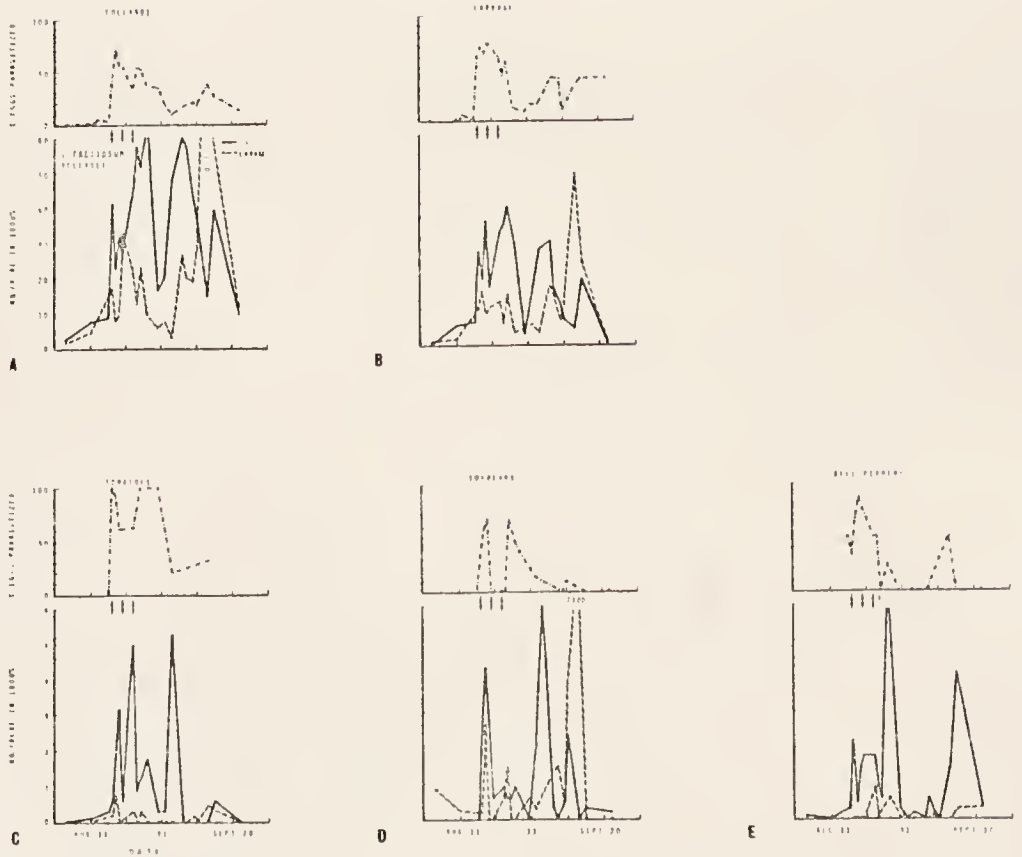


Fig. 26.--Parasitization of eggs of Plusiinae and relative densities of eggs and larvae of Plusiinae, primarily cabbage looper, on 5 crops in a 1-acre tobacco shade after 3 releases of ca. 230,000 female Trichogramma pretiosum per acre/release; A = collards; B = cabbage; C = tomatoes; D = soybeans; E = bell peppers. Parasitoid releases were made at 3-day intervals as host egg population densities began to increase.

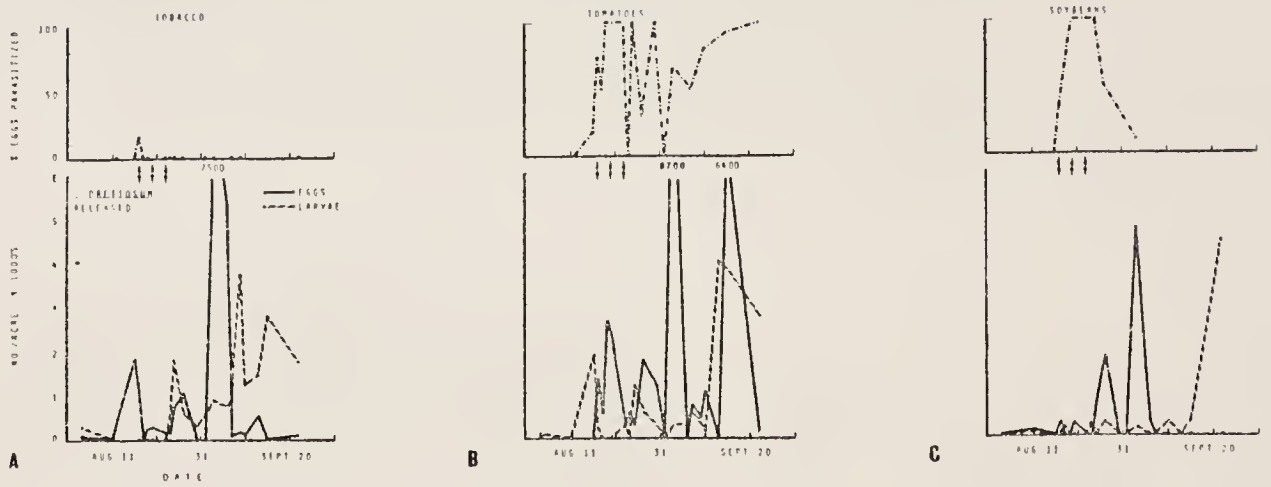


Fig. 27.--Parasitization of eggs of Heliothis spp. and relative densities of eggs and larvae of Heliothis spp. on 3 crops in a 1-acre tobacco shade after 3 releases of ca. 230,000 female Trichogramma pretiosum per acre/release. A = cigar-wrapper tobacco; B = tomatoes; C = soybeans. Parasitoid releases were made at 3-day intervals as host egg population densities began to increase.

Table 34.--Comparison of parasitization and hatch of eggs of Plusiinae and Heliothis spp. (1) collected prior to Trichogramma pretiosum releases, (2) collected immediately after the initial release of T. pretiosum until 2 days after the last release, and (3) collected 4 days after the final release until sampling was terminated.

Crops	No. eggs collected		% parasitization[a]	
	Plusiinae	Heliothis spp.	Plusiinae	Heliothis spp.
	Pre-release (Aug. 4-16)			
Total[b]	543	41	1.6	4.9
	Release (Aug. 17-25)			
Collards	1133	0	50.9	-
Cabbage	931	0	57.5	-
Bell peppers	39	(2)	56.4	(50.0)
Tomatoes	62	25	67.7	68.0
Soybeans	59	20	49.2	70.0
Bush beans	(1)	(2)	(0.0)	(0.0)
Tobacco	(9)	30	(11.1)	6.7
Total[b]	2234	79	54.0	43.0
	Post-release (Aug. 27-Sept. 22)			
Collards	1630	0	20.1	-
Cabbage	549	0	26.2	-
Bell peppers	31	(2)	22.6	(0.0)
Tomatoes	15	142	53.3	63.4
Soybeans	85	23	8.2	13.0
Bush beans	(5)	(9)	(0.0)	(0.0)
Tobacco	(3)	37	(0.0)	0.0
Total[b]	2303	213	21.2	43.7

Note: Three releases of a mean of ca. 230,000 female T. pretiosum per acre/release were made.

[a] χ^2 tests indicated that during the release and post-release periods amount of parasitization of eggs of Plusiinae (χ^2=21.56 and 19.06) and Heliothis spp. (χ^2=49.93 and 25.50) depended on crop characteristics. P was < 0.005 in all tests.

[b] Percent parasitization of all eggs collected.

larval numbers following these peaks of eggs were ca. 32,570 per acre on August 20, ca. 26,320 per acre on September 6, and ca. 102,220 per acre on September 13. Ca. 50% of the larvae found on September 13 were 1st- or 2nd-instar.

From the information in the previous paragraph, mortality for the first 2 egg peaks in collards can be estimated at 20 and 59%. Parasitism by Trichogramma spp. during these first 2 egg peaks was estimated at 45 and 35% from samples of Plusiinae eggs collected in collards during this period. When only 1st- and 2nd-instar larvae were used in calculating egg mortality during the 3rd egg peak, mortality was estimated at 15% compared with parasitism by Trichogramma spp. during this peak estimated from egg samples at 18%.

Suppression of cabbage looper larval infestations in cabbage also appeared to be largely due to parasitism by Trichogramma spp. (Fig. 26b). Calculations similar to those made for collards indicated mortality for the first 2 egg peaks in cabbage was 60 and 59% compared with parasitism by Trichogramma spp. estimated during these peaks at 63 and 55%. Estimate of mortality for the 3rd egg peak in cabbage was 13% compared with an estimate of parasitism by Trichogramma spp. at 41% during this peak. However, parasitism estimated from Plusiinae eggs collected in cabbage immediately prior to this peak (August 27-September 3) averaged only 12%.

Plusiinae larvae in tomatoes, soybeans, and bell peppers remained at low densities throughout the test period (Fig. 26c-e). In these crops, prior to the date when the 1st soybean loopers were released (August 31), egg peaks probably consisted mostly of cabbage looper.

Although eggs peaked during this "cabbage looper period," at over 5,000 per acre in tomatoes (Fig. 26c), 4000/acre in soybeans (Fig. 26d),

and 6,000/acre in bell peppers (Fig. 26e), in none of these crops were peaks of Plusiinae larval infestations >2,000/acre. Parasitism by Trichogramma spp. of eggs collected during these peak periods was high in tomatoes (61-100%), moderate in soybeans (31-67%), and low in bell peppers (0-25%). In addition to action by released T. pretiosum, mortality by other natural enemies and possible unsuitability of bell peppers as a good host for cabbage loopers (Sutherland 1966) might explain why relatively few larvae of Plusiinae were found, particularly in bell peppers.

Soybean looper

As has been mentioned previously, soybean loopers were not released into the 1-acre shade until August 31, and the last parasitoid release was made on August 23. Since increases of Plusiinae eggs were observed in soybeans and tomatoes immediately following releases of soybean loopers and most Plusiinae larvae collected and identified from soybeans during this period were soybean looper, a substantial number of the Plusiinae eggs found in these crops after August 31 were surely eggs of the soybean looper.

Also parasitization of these soybean looper eggs occurring after August 31 was likely to have been by progeny of released parasitoids since the last T. pretiosum release was made on August 23. Moreover, tentative identifications by L. R. Ertle indicate T. pretiosum was the only species of Trichogramma recovered from Plusiinae eggs collected in the 1-acre shade. (Species other than T. pretiosum were recovered from some eggs of Heliothis spp.)

Eggs of soybean looper apparently reached highest densities in soybeans (Fig. 26d). Parasitization of soybean looper eggs was low (ca. 10-14%) and the egg peak of 5,960 per acre on September 3 was followed by

larval numbers estimated at over 7,000/acre.

In tomatoes, peaks of Plusiinae eggs that occurred after soybean looper adult releases were similar to those in soybeans (Fig. 26d and c). Parasitism was moderate (ca. 20%), but larval numbers were never over 1,000 per acre, and appeared to be considerably reduced from potential numbers (Fig. 26c), in contrast to soybeans.

In bell peppers (Fig. 26e) parasitism during the last peak of Plusiinae eggs, a peak which may have included soybean looper eggs, was estimated at 0-50%. The experiment was terminated before the following peak of soybean looper larvae could be detected.

In the 1.3-acre soybean field, parasitization of artificially-introduced soybean looper eggs was 47.8% the first day after the 1st release of T. pretiosum and 23.0% the fourth day after the 2nd release. Parasitism was lower after the 3rd and 4th parasitoid release, but egg samples were too small to yield accurate estimates of parasitism.

Tobacco budworm

In cigar-wrapper tobacco of the 1-acre shade, T. pretiosum were ineffective against the tobacco budworm (Fig. 27a). Only 2 of 88 total eggs collected in cigar-wrapper tobacco were parasitized (Table 34).

In contrast to results in cigar-wrapper tobacco, parasitization of eggs of Heliothis spp. collected in tomatoes was often 100% and all levels of larval peaks were far lower than preceeding egg peaks (Fig. 27b). Similarly, the August 25-27 peak of eggs of Heliothis spp. in soybeans was probably suppressed considerably by T. pretiosum releases (Fig. 27c). All larvae collected from soybeans and most from tomatoes were identified as corn earworm. However, the occurrence of peak numbers of eggs in these 2 crops does coincide with tobacco budworm release periods (Fig. 27b and

c); therefore, many of the eggs of Heliothis spp. collected in tomatoes and soybeans were surely tobacco budworm.

Effect of hosts and host-habitats

The data in Table 34, particularly that summarized from tomatoes and soybeans, indicate that the released T. pretiosum may have been more effective in parasitizing eggs of Helicthis spp. than eggs of Plusiinae. Graham (1970), Oatman and Platner (1971), Boldt et al. (1973), and Ashley et al. (1974) also found that the Trichogramma species they worked with (possibly T. pretiosum in each case) were more effective in parasitizing eggs of Heliothis spp. than those of Plusiinae.

Moreover, parasitism by Trichogramma semifumatum (= T. pretiosum?) which had infected noctuid colonies of Stern and Shorey (1968) was generally higher for Heliothis spp. than Plusiinae. Also, their results indicated cabbage looper eggs were preferred over those of soybean loopers. In later investigations, Taylor and Stern (1971) found T. semifumatum might prefer cabbage loopers over tobacco budworms under some circumstances.

There appears to have been a "host-habitat effect" on rates of parasitization by T. pretiosum in the 1-acre shade similar to that discussed in Section III. Rate of parasitization of Plusiinae eggs seemed to be substantially higher in tomatoes than in other crops in which adequate samples were taken during the release period (Table 34). Also, although samples of eggs of Heliothis spp. were limited, parasitization of eggs of Heliothis spp. was generally highest in tomatoes. Graham (1970) also found that native T. semifumatum (= T. pretiosum?), parasitized a larger percentage of eggs of Plusiinae and Heliothis spp. collected in tomatoes than eggs collected in bell peppers, and wild tobacco, and cotton and corn.

Graham's (1970) data indicated that as densities of eggs of Plusiinae and Heliothis spp. decreased in tomatoes, parasitism of eggs of Plusiinae decreased in this crop. In my plots eggs of Plusiinae were at low densities in tomatoes relative to those in collards and cabbage. During the release period the mean ratio of densities of lepidopterous eggs (Plusiinae and imported cabbageworm) estimated in collards and cabbage vs. densities at which ♀ T. pretiosum were released, was ca. 1:3. In tomatoes this ratio (eggs of Plusiinae and Heliothis spp. vs. released ♀ T. pretiosum) was ca. 1:150. The released T. pretiosum may have been less effective in finding a high percentage of the numerous eggs of cabbage looper among the numerous imported cabbageworm eggs in collards and cabbage than in finding a high percentage of the less dense egg population in tomatoes.[1]

Another explanation might be that other lepidopterous hosts present in crops treated with T. pretiosum could have interferred with the desired suppression of the target pest. However, any parasitization of hosts other than the target hosts should have increased crop protection by suppressing population densities of other pest species, and producing more T. pretiosum for suppression of subsequent generations of target pests.

But collections of numerous eggs of imported cabbageworm, during periods of peak parasitization of eggs of Plusiinae and Heliothis spp., yielded few parasitized eggs (Table 35). Tentative identifications by L. R. Ertle indicated the egg parasitoids that were found from this host might be T. evanescens rather than the released T. pretiosum. Also, eggs

[1]The work of Lewis et al. (1971) and subsequent work show that kairomores produced by corn earworms can "hold" another Trichogramma spp. (T. evanescens) in a limited area and increase parasitization of eggs in that area. However, the "proper" kairomones and/or the "proper" Trichogramma spp. might not have come together in my test.

Table 35.--Parasitization rates of eggs of 3 non-target lepidopterous species in crops grown in a 1-acre tobacco shade (TS) and in a 1.3-acre soybean field (SBF) after releases of Trichogramma pretiosum.

Host	Total no. eggs	% parasitized	% hatched	% collapsed
Imported cabbageworm (TS)[a]	1,381	0.4	52.1	47.5
Tobacco hornworm (TS)[b]	14	7.1	92.9	0.0
Velvetbean caterpillar (TS)[c]	11	9.1	81.9	0.0
(SBF)[d]	50	36.0	62.0	2.0

Note: Ca. 230,000 ♀ T. pretiosum were released per acre in the tobacco shade on August 17, 20, and 23. Ca. 390,000 ♀ T. pretiosum were released per acre in the soybean field on August 23, 26, 30, and September 11.

[a]Collected August 5-September 1 on collards and cabbage in a tobacco shade.

[b]Collected August 27-September 15 on tobacco, bell peppers, and tomatoes in a tobacco shade.

[c]Collected September 10, 15, and 22 on soybeans in a tobacco shade.

[d]Collected August 24, September 6, 13, and 14 in a soybean field.

of tobacco hornworm, Manduca sexta (Johannson), and velvetbean caterpillar, collected in the 1-acre tobacco shade were seldom parasitized (Table 35). However, in the 1.3-acre soybean field, egg parasitism of velvetbean caterpillar averaged 36%. Sixty-eight percent of 28 eggs collected on September 13 (2 days after a release of ca. 370,000♀ T. pretiosum per acre) were parasitized.

Using supplemental releases, I showed that the cabbage looper, soybean looper, and tobacco budworm population densities can be suppressed substantially by T. pretiosum in several crops in northern Florida. Also rates of parasitization can be affected by timing of releases, host characteristics, host-habitat characteristics, and possibly by "competition" from alternate hosts.

Chrysopa carnea

In contrast to the results I obtained with T. pretiosum, C. carnea were not effective in reducing population densities of cabbage looper, soybean looper, and/or tobacco budworm. Although I found more larvae of Chrysopa spp. in release plots than in control plots (Table 36), few larvae, pupae, or adults of Chrysopa spp. were found from either whole plant inspection or D-vac samples. Despite the availability of eggs and larvae of cabbage looper (Fig. 28a and b) and imported cabbageworm as a food source on collards and cabbage after C. carnea releases, Chrysopa spp. were found on only 3 of 16 sampling dates in either whole plant inspection or D-vac samples in these crops.

Highest number of Chrysopa spp. (ca. 22,500 per acre) found on any crop occurred on August 28 in bush beans. The samples were, however, taken only 15 hr after releases were made and recovery was only 11% of the release estimate. Estimates of Chrysopa found per acre other than those

Table 36.--Relative numbers of larvae of Chrysopa spp. per 100 row-ft in release and control plots in crops in a 1-acre shade after supplemental releases of 2- to 7-day-old Chrysopa carnea larvae.

Date	Release[a]							Control plots		
	Bush bean	Tobacco	Soy-bean	Collard	Cabbage	Bell pepper	Toma-to	Bush bean, collard cabbage & tomato	Soy-bean	Bell pepper
					Whole plant inspections					
8/20,[b] 23, 24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
27[b]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	155.0	140.0	85.0	25.0	75.0	45.0	75.0	-	-	-
8/30, 9/1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9/3	0.0	0.0	2.0	0.0	0.0	2.0	0.0	0.0	0.0	2.0
6	2.0	17.0	2.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0
7	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	1.0	6.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$\bar{x}$[c]	0.8	0.1	0.8	0.3	0.0	0.3	0.6	0.0	0.0	0.1
			$\bar{x}$ = 0.4					$\bar{x}$ = 0.0		
					D-vac samples					
8/25	0.0	0.0	0.8	0.0	0.0	6.0	1.0	0.0	1.0	0.0
9/1	1.0	4.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	5.0	2.0	2.0	3.0	7.0	4.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	1.0	1.0
23	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0
$\bar{x}$	1.2	1.2	3.5	0.6	1.4	0.3	0.2	0.0	0.6	0.2
			$\bar{x}$ = 1.2					$\bar{x}$ = 0.1		

Note: No Chrysopa spp. were found in any of the crops prior to the release of C. carnea.

[a] C. carnea were released on 8/20, 27, and 9/4-5 (ca. $\bar{x}$=194,000 per acre/release) in all crops. On 8/16 releases (ca. 50,000/acre) were made in soybeans and collards.

[b] Counts were made prior to releases on these dates.

[c] Estimate for 8/28 not included.

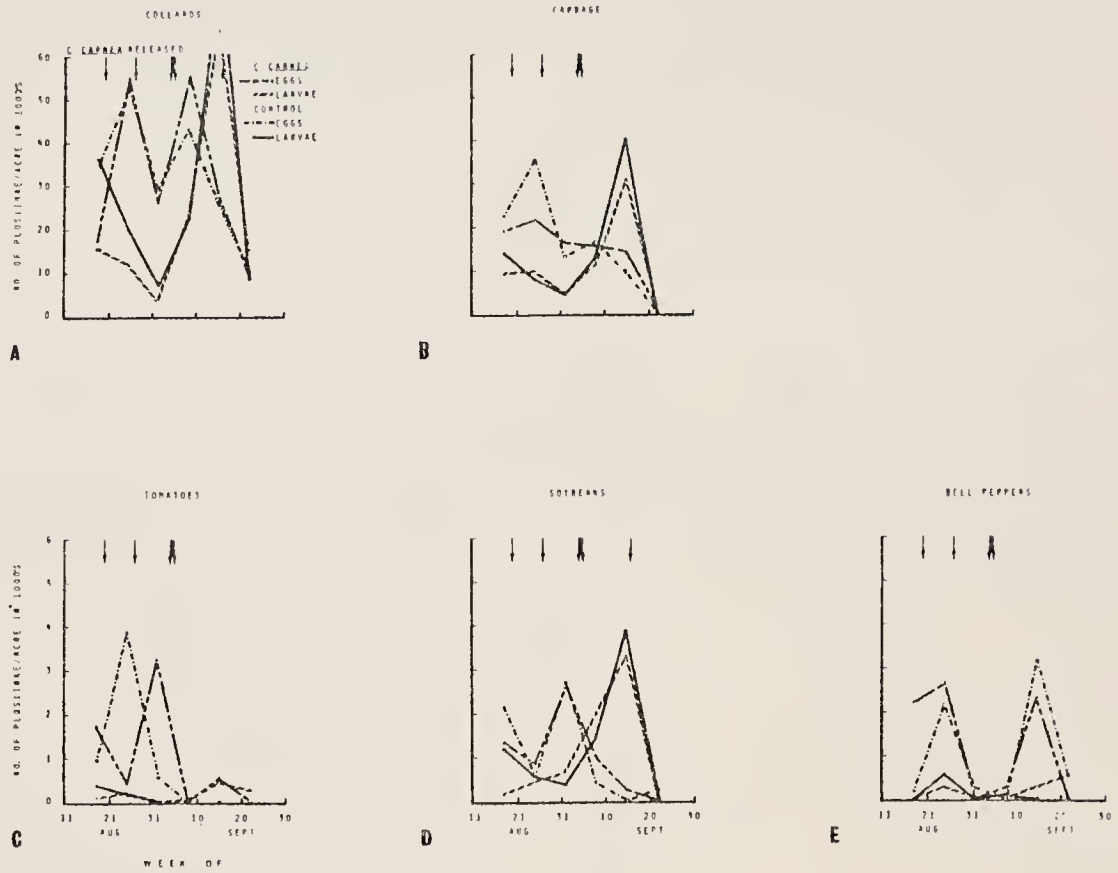


Fig. 28.--Relative number of eggs and larvae of Plusiinae per acre in release and in control plots in 5 crops in a 1-acre tobacco shade after 3 releases of ca. 194,000 two- to 5-day-old Chrysopa carnea larvae/acre/release. Releases were made at weekly intervals and an additional release of ca. 50,000 seven-day-old larvae per acre were released in soybeans; A = collards; B = cabbage; C = tomatoes; D = soybeans; E = bell peppers.

from August 28 were less than 2% of the numbers that were released.

Although mean numbers of cabbage looper larvae per acre in collards (Fig. 28a) and cabbage were lower in C. carnea release plots (24,320 and 11,840) than in control plots (28,280 and 13,190), the differences were not substantial (Fig. 28b), and in other crops with detectable numbers of cabbage loopers, mean numbers were higher in the release plots. In cabbage (Fig. 28b), tomatoes (Fig. 28c), bell peppers (Fig. 28d), the numbers of Plusiinae eggs were slightly lower in release plots than in control plots, but again the differences were not substantial. Also, Plusiinae eggs in soybeans (Fig. 28c) and collards (Fig. 28c) were at higher mean density in release plots than control plots even though these crops had received an extra application of C. carnea.

Results concerning predation of eggs and larvae of Heliothis spp. after C. carnea releases were similar to those I obtained for Plusiinae (Fig. 29). In cigar-wrapper tobacco, mean density for both eggs and larvae of Heliothis spp. were lower in release plots than in control plots (Fig. 29a). However, despite an apparent large difference in mean number of eggs (210 vs. 1690), differences in estimated number of larvae were slight (1260 vs. 1480). Also, the mean number of eggs and larvae estimated each week of sampling this crop was not always lower in the release plots.

In addition to the negative data obtained directly from counts for the released predator and the target pests, differences in crop damage in C. carnea release and control plots were slight or nil (Table 37). Yields of fruit in release plots were higher than in controls in bush beans, soybeans and tomatoes but differences were not significant. In bell peppers more fruit was estimated for control plots. These data as well as immature densities of Plusiinae and Heliothis spp. in release and control plots indicate little or no affect from the releases of C. carnea in the 1-acre shade.

Fig. 29.--Relative number of eggs and larvae of Heliothis spp. per acre in release and in control plots in 3 crops in a 1-acre tobacco shade after 3 releases of ca. 194,000 two- to 5-day-old Chrysopa carnea larvae/acre/release. Releases were made at weekly intervals and an additional release of ca. 50,000 seven-day-old larvae/acre were released in soybeans; A = cigar-wrapper tobacco; B = tomatoes; C = soybeans.

Table 37.--Rating of foliage damage and percent fruit damage for crops in a 1-acre shade after releases of 2- to 7-day-old Chrysopa carnea larvae.

Crop	Foliage damage[a,b]		% Fruit damage[b]	
	C. carnea release plots	C. carnea control plots	C. carnea release plots	C. carnea control plots
Bush beans	2.8a	2.4a	2.4a	1.4a
Tobacco	3.1a	3.2a	-	-
Soybeans	2.8a	2.8a	0.0a	0.0a
Collards	4.6a	4.6a	-	-
Cabbage	4.8a	5.2a	-	-
Bell peppers	1.7a	1.7a	0.4a	0.4a
Tomatoes	2.6a	2.6a		
Total			10.0a	8.6a
Ripe			30.8a	26.2a

Note: Three releases of C. carnea were made on release plots in all crops except soybeans and collards, in which 4 releases were made. Also, three releases of Trichogramma pretiosum were made over all plots.

[a]The rating system was used as a scale ranging from 1 to 6 as follows: (1) no apparent insect feeding, (2) 0-1% leaf area eaten, (3) 2-5% leaf area eaten, (4) 6-10% leaf area eaten, (5) 11-30% leaf area eaten, and (6) over 30% of the leaf area eaten.

[b]Paired numbers for each crop followed by the same letter are not significant according to the 1% level of student's t test.

In the test in the 3-row-ft sections of soybeans, number of soybean loopers in release and control plots were not significantly different at the 1% level of the student's t test. Only 3 larvae of C. carnea were found in the release plots for a mean of 0.8 C. carnea per 3 ft of row.

In the consumption test in the laboratory most of the C. carnea shipped from College Station lived and fed on the eggs or larvae presented them. They fed upon all species and stages of hosts presented in the test. A mean of 7.2 eggs were consumed in 48 hr; and 3.8 larvae were consumed in 24 hr.

Several reasons for the ineffectiveness of C. carnea in my field experiments can, of course, easily be proposed, although I have no "hard" data to support any of them. For instance, C. carnea have apparently not been found from previous collections in Florida (Whitcomb personal communication,[2] Tauber personal communication[3]), and this species of Chrysopa may not be adapted to this northern Florida region, its climate and its other characteristics. (However, 1 C. carnea adult was found in rye by me in the 8-acre cropping system during April, 1973, over 1 and 1/2 years and at least 5 miles from the nearest release point in the 1-acre shade test.)

Related to the previous "explanation", regular rainfall and prevalent moisture on the plants during the testing period in the 1-acre shade may have reduced the effectiveness of the released larvae of C. carnea for preying on eggs and larvae in the field. National Weather Service records for Quincy, indicate it rained on 21 of 34 days from August 30 (the initial

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[2]W. H. Whitcomb, Univ. of Florida, Gainesville, FL.

[3]Letter dated May 10, 1973 from Catherine A. Tauber, Dept. of Entomol., Cornell Univ., Ithaca, N.Y.

Table 38.--Weather conditions for August and September, 1971 at the North Florida Agricultural Research and Education Center, Quincy, FL.

Date		Amount rainfall	Max./Min. temperature (°F)	Min. % R.H.	Prevailing wind direction	Mean wind velocity (mph)	Mean % cloud cover[a]
Aug.	4	0.16	93/68	51	V	1.91	50
	5	0.12	92/70	58	V	1.58	60
	6	0.22	89/70	57	E	2.78	50
	7	0.00	90/70	60	E	2.08	60
	8	0.00	93/70	57	SE	1.54	50
	9	0.00	92/72	50	V	1.45	70
	10	0.00	91/71	57	V	1.54	60
	11	0.03	91/72	58	W	2.08	60
	12	0.00	90/72	-	NW	-	70
	13	0.00	90/70	60	E	2.50	30
	14	0.00	89/70	52	NE	2.16	30
	15	0.70	89/70	61	NE	2.75	90
	16	0.11	89/73	61	NE	2.50	90
	17	0.58	88/68	-	E	-	80
	18	0.04	89/69	68	E	1.70	70
	19	0.01	88/67	58	E	1.33	70
	20[b]	0.00	92/68	54	V	1.16	50
	21	0.07	93/70	52	V	1.42	60
	22	0.03	93/69	52	V	1.15	60
	23	0.02	89/71	64	W	1.38	70
	24	T[c]	92/70	51	W	1.50	60
	25	0.00	86/68	63	SE	1.58	90
	26	0.24	84/69	72	SE	1.79	90
	27[b]	0.00	89/69	57	V	1.66	70
	28	0.20	89/69	61	E	1.46	70
	29	0.18	87/69	72	E	2.00	80
	30	0.23	89/70	64	E	2.70	90
	31	T	88/71	64	E	2.70	70
Sep.	1	T	90/70	62	SE	3.04	60
	2	T	90/70	58	E	3.45	70
	3	0.08	82/72	68	E	4.20	90
	4[b]	0.31	82/72	66	E	2.92	90
	5[b]	0.00	89/71	62	E	3.17	70
	6	T	89/72	57	E	3.90	60
	7	0.02	89/69	54	E	3.90	70
	8	0.07	87/70	61	E	4.00	90
	9	1.07	87/71	68	E	4.45	80
	10	0.00	88/68	54	V	1.38	60
	11	T	89/69	55	W	2.58	80
	12	0.00	86/70	61	W	2.17	90
	13	0.00	85/65	38	NW	2.54	40
	14	0.00	89/56	37	W	1.66	10
	15	0.00	89/60	53	V	0.58	90
	16[b]	0.00	86/62	65	SE	1.45	90
	17	0.27	87/69	62	S	2.54	80
	18	0.00	89/66	56	NW	1.58	70
	19	0.00	91/64	49	V	1.08	30
	20	0.02	92/66	47	V	0.66	50
	21	0.00	91/66	56	E	1.37	40
	22	0.00	89/67	57	E	2.50	40

Note: Obtained from National Weather Service Records, Quincy, FL.

[a]This was calculated from data collected in Tallahassee, FL.

[b]C. carnea were released.

[c]T=Trace.

C. carnea release date) to September 22 (Table 38). For every release date but September 4 the records indicate it rained on the following day.

Another explanation might be that the abundance of alternate prey (imported cabbageworms, suckflies, diamondback moths, and aphids) interferred with predation by C. carnea on the target pests. The low recovery (less than 10%) of released C. carnea in whole plant inspection and D-vac samples in the tests presented, and in additional tests, indicates, however, few C. carnea may have survived after they were released. Still, in their early work in caged cotton in which 74-99% reduction of Heliothis spp. was attained, Ridgway and Jones (1968) recovered released C. carnea at low rates (25% or less). In addition, Kinzer et al. (1971) showed that despite significant control of Heliothis spp. in cotton by larvae of C. carnea at release rates of 30,000-100,000 per acre, a maximum of only about 8% of the larvae were "recovered" from estimates from whole plant inspections. In the 1-acre shade test, C. carnea should have been substantially easier to find in tobacco, collards, and bell peppers and probably more difficult to find in soybeans and tomatoes, than in the 2 to 5-ft tall cotton used in studies by Kinzer et al. (1971).

If C. carnea had been effective and if it had not discriminated against eggs parasitized by T. pretiosum, released C. carnea might have also fed on parasitized eggs and might have reduced potential suppression by succeeding T. pretiosum. Although studies have not been conducted to determine if C. carnea discriminate between parasitized eggs and normal eggs, studies by Boyd (1970) indicate larvae of C. carnea may prefer early instar lepidopterous larvae over eggs. He found that 1st-instar larvae of Heliothis spp. were preferred to eggs of Heliothis spp., as well as cotton aphids, Aphis gossipii Glover, and spider mites,

Tetranychus cinnabarinus (Boisduval).

In my tests some other hosts may have been preferred over Heliothis spp. and Plusiinae, or at least may have been competitive enough to prevent significant suppression of Heliothis spp. and/or Plusiinae after supplemental releases of C. carnea; or even more likely, the weather may have stopped effective predation by the released C. carnea. Of course, other factors were involved and may have been even more important in preventing suppression of the target pests with released C. carnea.

Summary

Three supplemental releases at 3 day intervals of a mean of ca. 230,000 female T. pretiosum per acre/release were effective in suppressing population densities of the cabbage looper, soybean looper, and tobacco budworm in some crops. High rates of egg parasitization and substantial suppression of larvae of Plusiinae and Heliothis spp. were attained in tomatoes which possessed moderate densities of the pests. Parasitization of Plusiinae eggs was moderate to high in soybeans and bell peppers, and in these crops Plusiinae larvae remained at low levels. Parasitization of cabbage looper eggs was high in collards and cabbage, crops in which cabbage looper eggs reached densities of over 60,000 per acre, and substantial suppression of cabbage looper larvae was achieved. Low rates of egg parasitization achieved in cigar-wrapper tobacco indicate suppression of lepidopterous pests in this crop with supplemental releases of T. pretiosum is not feasible.

Released T. pretiosum may have been more effective in parasitizing eggs of Heliothis spp. than eggs of Plusiinae in similar host-habitats. Also, parasitization of eggs in tomatoes was substantially higher than

in other crops tested.

Three releases of 194,000 two to 5-day-old larvae of C. carnea were not effective in suppressing densities of cabbage looper, soybean looper, or tobacco budworm in cigar-wrapper tobacco, soybeans, collards, cabbage, bell peppers, or tomatoes under conditions during our tests. However, laboratory tests showed that C. carnea shipped from College Station, TX to Quincy, FL would feed on eggs of cabbage looper, soybean looper, and tobacco budworm, and lst-instar larvae of cabbage looper and tobacco budworm.

SECTION VI

CONCLUSIONS

Cabbage Looper

Larval populations of the cabbage looper reached very high densities even under high suppression by parasitoids; however they were suppressed to low levels during mid- and late summer by nuclear polyhedrosis virus (NPV). Trichogramma pretiosum and Copidosoma truncatellum were the major parasitoids while Coleomegilla maculata and Hippodamia convergens were the major predators associated with the cabbage looper. Suppression of cabbage loopers by these predators, however, appeared to be relatively low.

Both adults and immatures of the cabbage looper were at low densities from December to March. Collards and cabbage were the preferred hosts at low and high density levels and these crops produced almost all of the cabbage loopers in the system. Occurrence of immature stages and trends of abundance were closely correlated with adult capture data.

Low population levels in the winter, preference for crucifers over a number of other crops, and susceptibility to NPV appear to be some of the weakest links in cabbage looper population development. Also, control of cocklebur might lower densities of cabbage loopers which threaten crops at some times in some areas.

Cabbage loopers are susceptible to Trichogramma pretiosum and can be suppressed substantially using 3 properly timed releases of

194,000 females per acre/release at 3-day intervals. However, suppression to sub-economic levels in some crops would often necessitate release at low host densities and/or require more assistance from other natural enemies. Cabbage loopers (and soybean loopers and tobacco budworms) were not suppressed in any crops by supplemental releases of numerous larvae of another entomophage, Chrysopa carnea, under the conditions of my experiments.

Soybean Looper

Populations of the soybean looper never reached high densities. They were measured at lowest levels from November to May. Soybean looper developed mostly on soybeans, its preferred host in the system, although tomatoes and peanuts may have also been important in producing some of the early developing soybean loopers during 1 year. Occurrence of developing immatures may be able to be predicted from adult capture data.

Trichogramma pretiosum, Copidosoma truncatellum, Apanteles marginiventris, and tachinids all were important parasitoids. Predaceous arthropods, especially Geocoris punctipes, appeared to be very important in suppressing soybean looper population densities to low levels. Incidence of disease was generally low.

Natural enemies, particularly predaceous arthropods, appear to be effective in regulating soybean loopers at very low densities, although several otner factors (low fecundity?, etc.) are surely involved. Low population levels in the winter and spring and preference for soybeans appear to be other vulnerable aspects of soybean looper populations. Also, control of cocklebur might help in preventing infestations of soybean looper in some crops during some seasons.

If outbreaks of soybean loopers occur in soybeans, high rates of parasitism of soybean looper eggs can be achieved by utilizing supplemental releases of T. pretiosum. T. pretiosum may also be effective against the soybean looper in other crops, especially tomatoes.

Tobacco Budworm

Populations of tobacco budworms reached high densities; however Cardiochiles nigriceps, the major parasitoids of this pest, did limit greatly the number of tobacco budworms reaching the pupal stage in tobacco during the summer. Adults and immatures were at especially low levels in samples taken from November to March. Tobacco was the preferred host but other hosts such as okra (in late summer and fall), white clover (in the spring), and wild hosts, including crimson clover, were also important in producing tobacco budworms. Immatures and at least trends of abundance may be able to be predicted from adult capture data.

Trichogramma pretiosum, Meteorus autographae, and Apanteles marginiventris were important parasitoids of the tobacco budworm on crops other than tobacco. Two other entomophages, Coleomegilla maculata and Hippodamia convergens were the major predators associated with the tobacco budworm in tobacco, but they were not effective in suppressing it to low levels. Predaceous arthropods appeared to be quite important in suppressing tobacco budworms in okra and white clover. Incidence of disease was low in most all crops.

Preference for tobacco and susceptibility to Cardiochiles nigriceps in tobacco appear to be the major weak links of the tobacco budworm although unfavorable weather conditions and other factors probably reduce the overwintering generation to low levels each year. Susceptibility

of tobacco budworm eggs to parasitism by Trichogramma spp. is a weak link in tomatoes, but is certainly not a vulnerable aspect of tobacco budworm (sub) populations in tobacco.

White clover and southern field peas were probably the most important reservoirs of parasitoids which affected population densities of tobacco budworms (and cabbage looper and soybean loopers). Green cloverworms and velvetbean caterpillars were probably the most important alternate hosts for some of these parasitoids. Also, white clover was the most important reservoir of predaceous arthropods.

Tomatoes are particularly suitable for suppression of some lepidopterous pests by utilizing supplemental releases of Trichogramma pretiosum. Eggs of both Plusiinae and Heliothis spp. are heavily parasitized in this crop.

REFERENCES

Ahmed, M. K. 1955. Comparative effect of Systox and schradan on some predators of aphids in Egypt. J. Econ. Entomol. 48:530-2.

Ahmed, M. K., L. D. Newsom, R. B. Emerson, and J. S. Roussel. 1954. The effect of Systox on some common predators of the cotton aphid. J. Econ. Entomol. 47:445-9.

Aldrich, J. M. 1927. Dipterous parasites of the migratory locust of tropical America, Schistocerca paranensis Burmeister. J. Econ. Entomol. 20:588-93.

Allee, W. C., O. Park, T. Park, A. E. Emerson, and K. P. Schmidt. 1949. Principles of animal ecology. W. B. Saunders Co., Philadelphia, PA. 837 p.

Allen, H. W. 1925. Biology of the red-tailed tachina fly, Winthemia quadripustulata Fabr. MS Agr. Exp. Sta. Tech. Bull. 12:8.

Anonymous. 1969. National Academy of Sciences. Insect-pest management and control. National Academy of Sciences Pub. 508 p.

Anonymous. 1971a. Cooperative Economic Insect Report. Vol. 21. Plant Protection Div., USDA, 784 p.

Anonymous. 1971b. Package meals for insects. Agr. Res., USDA. 19:3-4.

Anonymous. 1972a. Coop. Econ. Insect Rep. Vol. 22. Plant Protection Div., USDA. 806 p.

Anonymous. 1972b. Lacewing larvae: victor of the cottonfield. Agr. Res. USDA. 20:8-9.

Ashley, T. R., J. C. Allen, and D. Gonzalez. 1974. Successful parasitization of Heliothis zea and Trichoplusia ni eggs by Trichogramma. Environ. Entomol. 3:319-22.

Barber, G. W. 1936. Orius insidiosus (Say), an important natural enemy of the corn earworm. USDA Tech. Bull. 504. 24 p.

Barber, G. W. 1937. Seasonal availability of food plants of two species of Heliothis in eastern Georgia. J. Econ. Entomol. 30:150-8.

Barry, R. M. 1973. A note on the species composition of predators in Missouri soybeans. J. GA Entomol. Soc. 8:284-6.

Bartlett, B. R. 1964. Toxicity of some pesticides to eggs, larvae, and adults of the green lacewing, Chrysopa carnea. J. Econ. Entomol. 57:366-9.

Beegle, C. C. 1971. Effect of a nuclear polyhedrosis virus on the relationship between Trichoplusia ni and the parasite Hyposoter exiguae. Ph.D. thesis. Univ. of CA, Riverside, CA. 127 p.

Berger, R. W. 1963. Laboratory techniques for rearing Heliothis species on artificial medium. USDA, Agr. Res. Serv. 33. 4 p.

Boldt, P. E., N. Marston, and W. A. Dickerson. 1973. Differential parasitism of several species of lepidopteran eggs by two species of Trichogramma. Environ. Entomol. 2:1121-2.

Boling, J. C., and H. N. Pitre. 1971. Hostal plant preferences for oviposition by Trichoplusia ni, and efficiency of Apanteles marginiventris as a population regulator of T. ni in field-cage tests. J. Econ. Entomol. 64:411-2.

Bottrell, D. G., J. H. Young, R. G. Price, and R. H. Adams. 1968. Parasites reared from Heliothis spp. in Oklahoma in 1965 and 1966. J. Econ. Entomol. 61:1053-5.

Boyd, J. P. 1970. Feeding and searching behavior of Chrysopa carnea Stephens. Ph.D. thesis. TX A & M Univ., College Station, TX. 108 p.

Boyer, W. P., and W. A. Dumas. 1963. Soybean insect survey as used in Arkansas. Coop. Econ. Insect Rep. USDA 13:91-2.

Braun, R. A., and W. E. Bickley. 1963. The green lacewings of the genus Chrysopa in Maryland (Neuroptera: Chrysopidae). Univ. MD Agr. Exp. Sta. Bull. A-124. 18 p.

Brazzel, J. R., L. D. Newsom, J. S. Roussel, C. Lincoln, F. J. Williams, and G. Barnes. 1953. Bollworm and tobacco budworm as cotton pests in Louisiana and Arkansas. LA Agr. Exp. Sta. Tech. Bull. 482. 47

Britton, W. E. 1933. Plant pest handbook for Connecticut. I. Insects CN Agr. Exp. Sta. Bull. 344:89-90.

Brubaker, R. W. 1968. Seasonal occurrence of Voria ruralis, a parasite of the cabbage looper in Arizona, and its behavior and development in laboratory culture. J. Econ. Entomol. 61:306-9.

Burges, H. D., and N. W. Hussey. 1971. Microbial control of insects and mites. Academic Press, New York, NY. 861 p.

Burke, H. R., and D. F. Martin. 1956. The biology of three chrysopid predators of the cotton aphid. J. Econ. Entomol. 49:698-700.

Burleigh, J. G. 1971. Parasites reared from the soybean looper in Louisiana 1968-69. J. Econ. Entomol. 64:1550-1.

Burleigh, J. G. 1972. Population dynamics and biotic controls of the soybean looper in Louisiana. Environ. Entomol. 1:290-4.

Butler, G. D., Jr. 1958a. Braconid wasps reared from lepidopterous larvae in Arizona. 1957. Pan-Pacific Entomol. 34:221-3.

Butler, G. D., Jr. 1958b. Tachinid flies reared from lepidopterous larvae in Arizona. 1957. J. Econ. Entomol. 51:561-2.

Butler, G. D., Jr. 1965. Spanogonicus albofasciatus as an insect and mite predator. J. KS Entomol. Soc. 38:70-5.

Butler, G. D., T. R. Pfrimmer, and J. W. Davis. 1974. A model to describe the uniform buildup of populations of adult bollworms and cabbage loopers. Environ. Entomol. 3:978-80.

Callahan, P. S. 1958. Serial morphology as a technique for determination of reproductive patterns in the corn earworm, Heliothis zea (Boddie). Ann. Entomol. Soc. Amer. 51:413-28.

Cameron, J. W. M. 1971. Insect pathogens and their potential for regulation of insect populations. Proc. Tall Timbers Conf. Ecol. Control Habitat Management 3:267-77.

Canerday, T. D., and F. S. Arant. 1967. The looper complex in Alabama (Lepidoptera:Plusiinae). J. Econ. Entomol. 59:742-3.

Carner, G. R., M. Shepard, and S. G. Turnipseed. 1974. Seasonal abundance of insect pests of soybeans. J. Econ. Entomol. 67:487-93.

Chamberlin, F. S., and J. N. Tenhet. 1926a. Cardiochiles nigriceps Viereck, an important parasite of the tobacco budworm, Heliothis virescens (F.). J. Agr. Res. 33:21-7.

Chamberlin, F. S., and J. N. Tenhet. 1926b. Seasonal history and food habits of the tobacco budworm, Helicthis virescens (F.) in the southern tobacco growing region. J. Econ. Entomol. 19:611-14.

Chapman, J. W., and R. W. Glaser. 1915. A preliminary list of insects having wilt, with a comparative study of their polyhedra. J. Econ. Entomol. 8:140-9.

Chittenden, F. H. 1902. Some insects injurious to vegetable crops. USDA Div. Entomol. Bull. 33:60-9.

Clancy, D. W. 1969. Parasitization of cabbage and alfalfa loopers in southern California. J. Econ. Entomol. 62:1078-83.

Clausen, C. P. 1962. Entomophagous insects. McGraw-Hill Book Co., New York, NY. 688 p.

Cole, C. L., P. L. Adkisson, and R. E. Fye. 1973. Studies of the seasonal abundance of Heliothis larvae on cotton in the Presidio, Texas area. J. Econ. Entomol. 66:524-6.

Conrad, M. S. The spotted lady beetle, Coleomegilla maculata (DeGeer), as a predator of European corn boxer eggs. J. Econ. Entomol. 52:843-7.

Coppedge, J. R., R. L. Ridgway, and R. E. Kinzer. 1971. Natural populations of parasites and predators of Heliothis on oats, bermuda grass pasture, corn, grain sorghum, and cotton. Chapter II. In Programmed releases of Trichogramma and Chrysopa for control of Heliothis in 1971. Special Rep. 2. Cotton Insects Systemic Chemicals and Nutritional Investigations, SR, ARS, USDA, College Station, TX.

Creighton, C. S. 1973. Chemical insecticide and pathogens and resistance of cabbage looper to chemicals. Paper presented at Cabbage Looper Symp., Dallas, TX, Nov. 28, 1973.

Crumb, S. E. 1956. The larvae of Phalaenidae. U.S. Dep. Agr. Bull. 1135:252-4

DeBach, P., ed. 1964. Biological control of insect pests and weeds. Reinhold Publishing Co., New York, NY. 844 p.

DeBach, P. 1974. Biological control by natural enemies. Cambridge Univ. Press, New York, NY. 323 p.

DeBach, P., and K. S. Hagen. 1964. Manipulation of entomophagous species. p. 429-58. In P. DeBach, ed., Biological control of insect pests and weeds. Reinhold Publishing Co., New York, NY.

DeGant, F. 1930. Two new species of parasitic Hymenoptera (Braconidae) from Ohio. Proc. Entomol. Soc. WA 32:163-5.

DeLoach, C. J., and J. C. Peters. 1972. Effect of strip-planting vs. solid-planting on predators of cotton insects in southeastern Missouri, 1969. Environ. Entomol. 1:94-102.

Detrick, E. J. 1961. An improved backpack motor fan for suction sampling of insect populations. J. Econ. Entomol. 54:394-5.

Dinkins, R. L., J. R. Brazzel and C. A. Wilson. 1970a. Seasonal incidence of major predaceous arthropods in Mississippi cotton fields. J. Econ. Entomol. 63:814-7.

Dinkins, R. L., J. R. Brazzel, and C. A. Wilson. 1970b. Species and relative abundance of Chrysopa, Geocoris and Nabis in Mississippi cotton fields. J. Econ. Entomol. 63:660-1.

Doutt, R. L., and K. S. Hagen. 1949. Periodic colonization of Chrysopa californica as a possible control of mealybugs. J. Econ. Entomol. 42:560.

Doutt, R. L., and K. S. Hagen. 1950. Biological control measures applied against Pseudococcus maritimus on pears. J. Econ. Entomol. 43:94-6.

Doutt, R. L., and R. F. Smith. 1971. The pesticide syndrome—diagnosis and suggested prophylaxis. p. 3-14. In C. B. Huffaker. ed., Biological control. Plenum Press, New York, NY.

Dulmage, H. T. 1972. Pathogens. p. 57-64. In Distribution, abundance, and control of Heliothis species in cotton and other host plants. Southern Coop. Series Bull. No. 169.

Dustan, A. G. 1932. Vegetable insects and their control. Can. Dep. Agr. Entomol. Bull. 32:43-44.

Dysert, R. J. 1973. The use of Trichogramma in the USSR. Proc. Tall Timbers Conf. Ecol. Control Habitat Management 4:165-73.

Ehler, L. E., K. G. Eveleens, and R. van den Bosch. 1973. An evaluation of some natural enemies of cabbage looper on cotton in California. Environ. Entomol. 2:1009-15.

Ehler, L. E., and R. van den Bosch. 1974. An analysis of the natural biological control of Trichoplusia ni (Lepidoptera: Noctuidae) on cotton in California. Can. Entomol. 106:1068-73.

Eichlin, T. D., and H. B. Cunningham. 1969. Characters for identification of some Plusiinae caterpillars of the southeastern United States. Ann. Entomol. Soc. Amer. 62:507-10.

Elsey, K. D. 1969. Field mortality of the cabbage looper with special emphasis on the tachinid parasite, Voria ruralis Fallen. Ph.D. thesis. NC State Univ. Raleigh, NC. 125 p.

Elsey, K. D. 1971. Stilt bug predation on artificial infestation of tobacco hornworm eggs. J. Econ. Entomol. 64:772-3.

Elsey, K. D. 1972. Predation of eggs of Heliothis spp. on tobacco. Environ. Entomol. 1:433-8.

Elsey, K. D. 1973. Effect of insecticide treatments on Jalysus spinosus, an insect predator found on tobacco. Environ. Entomol. 2:240-3.

Elsey, K. D., and R. L. Rabb. 1967. Biology of the cabbage looper on tobacco in North Carolina. J. Econ. Entomol. 60:1636-9.

Elsey, K. D., and R. L. Rabb. 1970. Analysis of the seasonal mortality of the cabbage looper on North Carolina. Ann. Entomol. Soc. Amer. 63:1591-1604.

Endris, R. G. 1973. The biology and overwintering of the cabbage looper and soybean looper in Florida. M.S. thesis. University of FL. 58 p.

Ewing, K. P., and E. E. Ivy. 1943. Some factors influencing bollworm population and damage. J. Econ. Entomol. 36:602-6.

Falcon, L. A., W. R. Bauer, G. T. Okumura, V. E. Burton, and R. van den Bosch. 1967a. Light traps and moth identification . . . an aid for detecting insect outbreaks. CA Agr. Exp. Sta. (Berkeley) Leafl. 197. 16 p.

Falcon, L. A., R. van den Bosch, L. K. Etzel, C. A. Ferris, and L. K. Stromberg. 1967b. Light traps as detection devices for moths of cabbage looper and bollworm. CA Agr. 21:12-4.

Falcon, L. A., R. van den Bosch, C. A. Ferris, L. K. Stromberg, L. K. Etzel, R. E. Stinner, and T. F. Leigh. 1968. A comparison of season-long cotton-pest-control programs in California during 1966. J. Econ. Entomol. 61:633-42.

Fife, L. C., and H. M. Graham. 1966. Cultural control of overwintering bollworm and tobacco budworm. J. Econ. Entomol. 59: 1123-5.

Forbes, S. A. 1883. The food relations of predaceous beetles. Noxious and beneficial insects. 12th Rep. State Entomol. IL. 105-20 p.

Force, D. C. 1972. r- and K-strategists in endemic host-parasitoid communities. Bull. Entomol. Soc. Amer. 18:135-7.

Fye, R. E. and C. G. Jackson. 1973. Overwintering of Chelonus blackburni in Arizona. J. Econ. Entomol. 66:807-8.

Fye, R. E., and D. J. Larsen. 1969. Preliminary evaluation of Trichogramma minutum as a released regulator of lepidopterous pests of cotton. J. Econ. Entomol. 62:1291-6.

Gentry, C. R., J. R. Young, and R. L. Burton. 1973. Effectiveness of blacklight-chemosterilant feeder and Trichogramma spp. in reducing egg hatch of Heliothis spp. in a large field cage. Environ. Entomol. 2:159-61.

Getzin, L. W. 1961. Spicaria rileyi (Farlow) Charles, an entomogenous fungus of Trichoplusia ni (Hubner). J. Insect Pathol. 3:2-10.

Graham, H. M. 1970. Parasitism of eggs of bollworms, tobacco budworms, and loopers by Trichogramma semifumatum in the lower Rio Grande Valley, Texas. J. Econ. Entomol. 53:686-8.

Graham, H. M., and O. T. Robertson. 1970. Host plants of Heliothis virescens and H. zea (Lepidoptera: Noctuidae) in the lower Rio Grande Valley, Texas. Ann. Entomol. Soc. Amer. 63:1261-5.

Graham, H. M., N. S. Hernandez, Jr., and J. R. Llanes. 1972. The role of host plants in the dynamics of populations of Heliothis spp. Environ. Entomol. 1:424-31.

Grayson, J. N. 1944. Two important parasites of the tobacco budworm. J. Econ. Entomol. 37:712-3.

Greene, G. L. 1971. Biology and ecology of the cabbage looper. Annu. Rep. of Research Progress of Coop. Agreement 12-14-100-10472(33), July. 59 p.

Greene, G. L. 1973. Seasonal populations of cabbage loopers: eggs and larvae in North America. Paper presented at Cabbage Looper Symp., Dallas, TX, Nov. 28, 1973.

Greene, G. L., W. G. Genung, R. B. Workman, and E. G. Kelsheimer. 1969. Cabbage looper control in Florida—a cooperative program. J. Econ. Entomol. 62:798-800.

Greene, G. L., and R. Thurston. 1971. Ovipositional preference of Heliothis virescens for Nicotiana species. J. Econ. Entomol. 64:641-3.

Gudauskas, R. T., and T. D. Canerday. 1966. Pathogenicity of Spicaria rileyi to Pseudoplusia includens. J. Invert. Pathol. 8:277.

Habeck, D. H. 1968. Annotated key to the Plusiinae moths of Florida (Lepidoptera: Noctuidae). FL. Dep. of Agr. Div. of Plant Industry. Entomol. Circ. 72. 2 p.

Hagen, K. S. 1962. Biology and ecology of predaceous Coccinellidae. Annu. Rev. Entomol. 7:289-326.

Hagen, K. S., R. van den Bosch, and D. L. Dahlston. 1971. The importance of naturally-occurring biological control in the western United States. p. 253-93. In C. B. Huffaker, ed., Biological control. Plenum Press, New York, NY.

Harcourt, D. G., R. H. Backs, and L. M. Cass. 1955. Abundance and relative importance of caterpillars attacking cabbage in eastern Ontario. Can. Entomol. 87:400-6.

Harding, W. C., Jr., J. G. Hartstock, and G. G. Rohwer. 1966. Black-light trap standards for general insect surveys. Bull. Entomol. Soc. Amer. 12:31-2.

Harper, J. D., and G. R. Carner. 1973. Incidence of Entomophthora spp. and other natural agents in populations of Pseudoplusia includens and Trichoplusia ni. J. Invert. Pathol. 22:8-5.

Harrison, P. K., and R. W. Brubaker, 1943. The relative abundance of cabbage caterpillars on cole crops grown under similar conditions. J. Econ. Entomol. 36:589-92.

Hartstack, A. W., Jr., and J. P. Hollingsworth. 1973. A computer model for predicting Heliothis populations. Trans. Amer. Soc. Agr. Eng. 17:112-5.

Hartstack, A. W., Jr., J. P. Hollingsworth, R. L. Ridgway, and J. R. Coppedge. 1973. A population dynamics study of the bollworm and the tobacco budworm with light traps. Environ. Entomol. 2:244-52.

Hasse, W. L. 1971. Predaceous arthropods of Florida soybean fields. M.S. thesis. Univ. of FL. 67 p.

Hayslip, N.C., W. G. Genung, E. G. Kelsheimer and J. W. Wilson. 1953. Insects attacking cabbage and other crucifers in Florida. FL. Agr. Exp. Bull. 534. 57 p.

Hendricks, D. E., H. M. Graham, R. J. Guerra, and C. T. Perez. 1973. Comparisons of the numbers of tobacco budworms and bollworms caught in sex pheromone traps vs. blacklight traps in lower Rio Grande Valley, Texas. Environ. Entomol. 2:911-5.

Henneberry, T. J., and A. N. Kishaba. 1966. Cabbage loopers. p. 461-78. In C. N. Smith, ed., Insect colonization and mass production. Academic Press, New York, NY.

Henry, P., and P. L. Adkisson. 1965. Seasonal abundance of bollworms and tobacco budworms on a typical cotton plantation. TX Agr. Exp. Sta. MP 767. 6 p.

Hensley, S. D., L. D. Newsom, and J. Chaplin. 1964. Observations on the looper complex of the noctuid subfamily Plusiinae. J. Econ. Entomol. 57:1006-7.

Hoffman, J. D., L. R. Ertle, J. B. Brown, and F. R. Lawson. 1970. Techniques for collecting, holding, and determining parasitism of lepidopterious eggs. J. Econ. Entomol. 63:1367-9.

Hoffman, J. D., C. M. Ignoffo, and W. A. Dicerson. 1975. In vitro rearing of the endoparasitic wasp, Trichogramma pretiosum. Ann. Entomol. Soc. Amer. 68:335-6.

Hofmaster, R. N. 1961. Seasonal abundance of the cabbage looper as related to light trap collections, precipitation, temperature and the incidence of a nuclear polyhedrosis virus. J. Econ. Entomol. 54:796-8.

Hollingsworth, J. P., and A. W. Hardstack, Jr. 1972. Effect of components on insect light trap performance. Trans. Amer. Soc. Agr. Eng. 15:924-7.

Hostetter, D. L. 1971. A virulent nuclear polyhedrosis virus of the cabbage looper, Trichoplusia ni recovered from the abdomen of sarcophagid flies. J. Invert. Pathol. 17:130-1.

Huckett, H. C. 1940. Non-arsenical dusts for cauliflower and cabbage-worm control on Long Island. NY Agr. Exp. Sta. (Geneva) Bull. 695. 58 p.

Huffaker, C. B., ed. 1971. Biological control. Plenum Press, New York, NY. 511 p.

Huffaker, C. B. 1974. Some implications of plant-arthropod and higher-level, arthropod-arthropod food links. Environ. Entomol. 3:1-9.

Huffaker, C. B., and C. E. Kennett. 1956. Experimental studies on predation: predation of cyclamen mite populations in Califronia. Hilbardia 24:191-222.

Huffaker, C. B., P. S. Messenger, and P. DeBach. 1971. The natural enemy component in natural control and the theory of biological control. p. 16-67. In C. B. Huffaker, ed., Biological control. Plenum Press, New York, NY.

Huffaker, C. B., M. van de Vrie, and J. A. McMurtry. 1970. Ecology of tetranychid mites and their natural enemies: a review. II. Tetranychids populations and their possible control by predators. Hilgardia 40:391-458.

Jackson, C. G., D. E. Bryan, and R. Patana. 1969. Laboratory studies of Eucelatoria armigera, a tachinid parasite of Heliothis spp. J. Econ. Entomol. 52:908-10.

Janes, M. L., and G. L. Greene. 1970. An unusual occurrence of loopers feeding on sweet corn ears in Florida. J. Econ. Entomol. 63: 1334-65.

Jensen, R. L., L. D. Newson, and J. Gibbens. 1974. The soybean looper: Effect of adult nutrition on oviposition, mating frequency, and longevity. J. Econ. Entomol. 67:467-70.

Jones, R. L., W. J. Lewis, M. Beroza, B. A. Bierl, and A. N. Sparks. 1973. Host-seeking stimulant (kairomones) for the egg parasite. Trichogramma evanescens. Environ. Entomol.

Kincaid, R. R. 1960. Shade tobacco growing in Florida. FL Agr. Exp. Sta. Bull. 136. 41 p.

Kinzer, R. E., J. R. Coppedge, S. L. Jones, and R. L. Ridgway. 1971. Releases of Chrysopa larvae for control of Heliothis. Chapter XIII. In Programmed releases of Trichogramma and Chrysopa for control of Heliothis in 1971. Special Rep. 2. Cotton Insects Systemic Chemicals and Nutritional Investigations, SR, ARS, USDA, College Station, TX.

Kishaba, A. N., W. W. Wolf, H. R. Toba, A. F. Howland, and T. Gibson. 1970. Light and synthetic pheromone as attractants for male cabbage loopers. J. Econ. Entomol. 63:1417-20.

Lawson, F. R. 1959. The natural enemies of the hornworms on tobacco. (Lepidoptera: Sphingidae). Ann. Entomol. Soc. Amer. 52:741-55.

Lewis, W. J., and J. R. Brazzel. 1966a. Biological relationships between Cardiochiles nigriceps and the Heliothis complex. J. Econ. Entomol. 59:820-3.

Lewis, W. J., and J. R. Brazzel. 1966b. Incidence of parasitic insects of the bollworm in Mississippi. MS Agr. Exp. Sta. Bull. 727: 3-8.

Lewis, W. J., and J. R. Brazzel. 1968. A three-year study of parasites of the bollworm and tobacco budworm in Mississippi. J. Econ. Entomol. 61:673-6.

Lewis, W. J., J. R. Brazzel, and S. Bradleigh Vinson. 1967. Heliothis subflexa, a host for Cardiochiles nigriceps. J. Econ. Entomol. 60:615-6.

Lewis, W. J., R. L. Jones, D. A. Nordlund, and H. R. Gross, Jr. 1975. Kairomones and their use for management of entomphagous insects: II. Mechanisms causing increase in rate of parasitization by Trichogramma spp. J. Chem. Ecol. 1:349-360.

Lewis, W. J., A. N. Sparks, and L. M. Redlinger. 1971. Moth odor: a method of host-finding by Trichogramma evanescens. J. Econ. Entomol. 64:557-8.

Lincoln, C. 1972. Seasonal abundance. p. 2-7. In Distribution, abundance, and control of Heliothis species in cotton and other host plants. S. Coop. Series Bull. 169.

Lincoln, C., J. R. Phillips, W. H. Whitcomb, G. C. Dowell, W. P. Boyer, K. O. Bell, G. L. Dean, C. J. Matthews, J. B. Graves, L. D. Newson, D. F. Clover, J. R. Bradley, and J. L. Bagent. 1967. The bollworm—tobacco problem in Arkansas and Louisiana. Arkansas Agr. Exp. Sta. Bull. 720:1-66.

Lingren, P. D. 1969. Approaches to the management of Heliothis spp. in cotton with Trichogramma spp. Proc. Tall Timbers Conf. Ecol. Control Habitat Management 1:205-17.

Lingren, P. D. 1970. Biological control—can it be effectively used in cotton production today? Proc. 2nd Annu. TX. Conf. on Insects, Plant Disease, Weed, and Brush Control, TX A & M Univ., College Station, TX p. 236-40.

Lingren, P. D., and R. L. Ridgway. 1967. Toxicity of five insecticides to several insect predators. J. Econ. Entomol. 60:1639-41.

Lingren, P. D., R. J. Guerra, J. W. Nickelsen, and C. White. 1970. Hosts and host-age preference of Campoletis perdistinctus. J. Econ. Entomol. 63:518-22

Lingren, P. D., R. L. Ridgway, C. B. Cowan, Jr., J. W. Davis, and W. C. Watkins. 1968a. Biological control of the bollworm and the tobacco budworm by arthropod predators affected by insecticides. J. Econ. Entomol. 61:1521-5.

Lingren, P. D., R. L. Ridgway, and S. L. Jones. 1968b. Consumption by several common arthropod predators of eggs and larvae of two Heliothis species that attack cotton. Ann. Entomol. Soc. Amer. 61:613-9.

Livingston, J. M., and W. C. Yeariam. 1972. A nuclear polydedrosis virus of Pseudoplusia includens (Lepidoptera: Noctuidae). J. Invert. Pathol. 19:107-12.

Lopez, Juan DeDios. 1973. Comparative efficiency of four insect predators of Heliothis spp. M.S. thesis. TX A & M Univ. College Station, TX 36 p.

Lukefahr, M. J., and T. N. Shaver. 1972. The potential of resistant cottons in the suppression of Heliothis populations. p. 27-32. In Distribution, abundance, and control of Heliothis species in cotton and other host plants. S. Coop. Series Bull. 169.

MacPhee, A. W., and C. R. MacLellan. 1971. Cases of natural-occurring biological control in Canada. p. 312-28. In C. B. Huffaker, ed., Biological control. Plenum Press, New York, NY.

McKinney, K. B. 1944. Cabbage looper as a pest of lettuce in the southwest. U. S. Dep. Agr. Tech. Bull. 846. 30 p.

McMurtry, J. A., C. R. Huffaker, and M. van de Vrie. 1970. Ecology of tetranychid mites and their natural enemies: A review. I. Tetranychid enemies. Their biological characters and the impact of spray practices. Hilgardia 40:331-90.

Mitchell, E. R. 1972. Female cabbage loopers inhibit attraction of soybean loopers. J. Econ. Entomol. 1:444-6.

Mitchell, E. R. 1973a. Noctural activity of adults of three species of loopers based on collections in pheromone traps. Environ. Entomol. 2:1078-80.

Mitchell, E. R. 1973b. Overwintering and migration of the cabbage looper. Paper presented at Cabbage Looper Symp., Dallas, TX, Nov. 28, 1973.

Mitchell, E. R., R. B. Chalfant, G. L. Greene, and C. S. Creighton. 1975. Soybean looper: populations in Florida, Georgia, and South Carolina as determined with pheromone—baited BL traps. J. Econ. Entomol. 68:747-50.

Mitchell, E. R., J. C. Webb, R. W. Hines, J. W. Stanley, R. G. Endris, D. A. Linquist, and S. Masuda. 1972. Evolution of cylindrical electric grids as pheromone traps for loopers and tobacco hornworms. Environ. Entomol. 1:365.

Mitchell, T. B. 1961. Coop. Econ. Insect Rep. U. S. Dep. Agr. 11:38.

Morgan, A. C., and F. S. Chamberlin. 1927. The tobacco budworm and its control in the Georgia and Florida tobacco growing region. U. S. Dep. Agr. Farm. Bull. 1531:1-9.

Morishita, F. S., R. N. Jefferson, S. T. Besemer, and W. A. Humphrey. 1967. Pseudoplusia includens—a pest of floricultural crops in southern California. J. Econ. Entomol. 60:1758.

Muesebeck, C. F. W., and K. V. Krombein. 1951. Hymenoptera of America north of Mexico. Synoptic catalog. U. S. Dep. Agr. Monogr. 2. 1420 p.

Neal, T. M. 1974. Predaceous arthropods in the Florida soybean agroecosystem. M.S. thesis. Univ. of FL. Gainesville, FL. 196 p.

Neal, T. M., G. L. Greene, F. W. Mead, and W. H. Witcomb. 1972. Spanogonicus albofasciatus (Hemiptera: Miridae): a predator in Florida soybeans. FL Entomol. 55:247-50.

Neal, T. M., and W. H. Whitcomb. 1972. Odonata in the Florida soybean agroecosystem. FL Entomol. 55:107-14.

Nemec, S. J. 1971. Effects of lunar phases on light trap collections and populations of bollworm moths. J. Econ. Entomol. 64:860-4.

Neunzig, H. H. 1963. Wild host plants of the corn earworm and the tobacco budworm in eastern North Carolina. J. Econ. Entomol. 56:135-9.

Neunzig, H. H. 1969. The biology of the tobacco budworm and the corn earworm in North Carolina with particular reference to tobacco as a host. NC Agr. Exp. Sta. Tech. Bull. 196. 76 p.

Newsom, L. D. 1972. Theory of population management for Heliothis spp. in cotton. p. 80-92. In Distribution, abundance, and control of Heliothis species in cotton and other host plants. S. Coop. Ser. Bull. 169.

Noble, L. W., and H. M. Graham. 1966. Behavior of Campoletis perdistinctus (Viereck) as a parasite of the tobacco budworm. J. Econ. Entomol. 59:118-20.

Oatman, E. R. 1966. An ecological study of cabbage looper and imported cabbageworm populations on cruciferous crops in southern California. J. Econ. Entomol. 59:1134-9.

Oatman, E. R., and G. R. Platner. 1969. An ecological study of insect populations on cabbage in southern California. Hilgardia 40:1-40.

Oatman, E. R., and G. R. Platner. 1971. Biological control of the tomato fruitworm, cabbage looper, and hornworms on processing tomatoes in souther California, using mass releases of Trichogramma pretiosum. J. Econ. Entomol. 64:501-6.

Oatman, E. R., and G. R. Platner. 1972. An ecological study of lepidopterous pests affecting lettuce in coastal southern California. Environ. Entomol. 1:202-4.

Oatman, E. R., G. R. Platner, and P. D. Greany. 1968. Parasitization of imported cabbageworm and cabbage looper eggs on cabbage in southern California, with notes on the colonization of Trichogramma evanescens. J. Econ. Entomol. 61:724-30.

Odum, E. P. 1959. Fundamentals of ecology. W. B. Saunders Co., Philadelphia, PA. 546 p.

Orphanides, G. M., D. Gonzalez, and B. R. Bartlett. 1971. Identification and evaluation of pink bollworm predators in southern California. J. Econ. Entomol. 64:421-4.

Parker, F. D. 1971. Management of pest populations by manipulating densities of both hosts and parasites through periodic releases. p. 365-76. In C. B. Huffaker, ed., Biological control. Plenum Press, New York, NY.

Parker, F. D., and R. D. Pinnell. 1972. Effectiveness of Trichogramma spp. in parasitizing eggs of Pieris rapae and Trichoplusia ni. 1. Field studies. Environ. Entomol. 1:785-9.

Payne, J. A., and S. G. Polles. 1974. Pecan: A new host for tobacco budworms and corn earworms. J. Econ. Entomol. 67:295-6.

Peck, O. 1963. A catalogue of the Nearctic Chalcidoidea (Insects: Hymenoptera). Can. Entomol. Suppl. 30. 1092 p.

Peterson, A. 1964. Egg types among moths of the Noctuidae (Lepidoptera). FL Entomol. 47:71-91.

Pierce, W. D., R. A. Cushman, and E. E. Hood. 1912. The insect enemies of the cotton boll weevil. U. S. Dep. Agr. Bull. Bur. Entomol. 100:1-99.

Pimentel, D. 1961a. An evaluation of insect resistance in broccoli, brussel sprouts, cabbage, collards, and kale. J. Econ. Entomol. 54:156-8.

Pimentel, D. 1961b. Natural control of caterpillar populations on cole crops. J. Econ. Entomol. 54:889-92.

Poe, S. L. 1972. Population of insect pests on commodities grown on the west coast of Florida in 1972. Bradenton AREC Res. Rep. CC72-10, Bradenton, FL, Dec. 7, 1972. 8 p.

Quaintance, A. L. 1896. Insect enemies of truck and garden crops. FL Agr. Exp. Sta. Bull. 34:278-80.

Quaintance, A. L., and F. C. Bishopp. 1905. The cotton bollworm. U. S. Dep. Agr. Farmers' Bull. 212:1-32.

Rabb, R. L. 1960. Biological studies of Polistes in North Carolina (Hymenoptera: Vespidae). Ann. Entomol. Soc. Amer. 53:111-21.

Rabb, R. L. 1971. Naturally-occurring biological control on the eastern United States, with particular reference to tobacco insects. p. 294-311. In C. B. Huffaker, ed., Biological control. Plenum Press, New York, NY.

Rabb, R. L., and J. R. Bradley. 1968. The influence of host plants on parasitism of eggs of the tobacco hornworm. J. Econ. Entomol. 61:1249-57.

Radcliffe, E. B., and R. K. Chapman. 1966. Varietal resistance to insect attack in various cruciferous crops. J. Econ. Entomol. 59:120-5.

Reid, W. J., Jr., and C. O. Bare. 1952. Seasonal populations of cabbage caterpillars in Charleston, South Carolina. J. Econ. Entomol. 45:696-9.

Reynolds, H. T. 1971. A world review of the problem of insect population upsets and resurgences caused by pesticide chemicals. p. 108-12. In J. E. Swift, ed., Agricultural chemicals-harmony or discard for food-people-environment. CA Div. Agr. Sci.

Ridgway, R. L. 1969. Control of bollworm and tobacco budworm through conservation and augmentation of predaceous insects. Pro. Tall Timbers Conf. Ecol. Control Habitat Mangement. 1:127-44.

Ridgway, R. L. 1972. Use of parasites, predators and microbial agents in management of insects pests of crops. p. 51-60. In implementing practical pest management strategies. Proc. Nat. Ext. Insect-Pest Management Workshop, Purdue Univ. 206 p.

Ridgway, R. L., and S. L. Jones. 1968. Field-cage releases of Chrysopa carnea for suppression of populations of the bollworm and the tobacco budworm on cotton. J. Econ. Entomol. 61:892-8.

Ridgway, R. L., and S. L. Jones. 1969. Inundative releases of Chrysopa carnea for control of Heliothis on cotton. J. Econ. Entomol. 62: 177-80.

Ridgway, R. L., and R. E. Kinzer. 1974. Chrysopids as predators of crop pests. Entomophaga. 7:45-51.

Ridgway, R. L., R. E. Kinzer, and R. K. Morrison. 1974. Production and supplemental releases of parasites and predators for control of insect and spider mite pests of crops. p. 110-6. In F. G. Maxwell, and F. A. Harris, ed., Proceedings of the summer institute on biological control of plant insects and dieseases. Univ. Press of MS, Jackson, MS.

Ridgway, R. L., and P. D. Lingren. 1972. p. 48-56. In Predaceous and parasitic arthropods as regulators of Heliothis populations. S. Coop. Ser. Bull. 169.

Ridgway, R. L., P. D. Lingren, C. B. Cowan, and J. W. Davis. 1967. Populations of arthropod predators, and Heliothis spp. after application of systemic insecticides to cotton. J. Econ. Entomol. 60:1012-6.

Ridgway, R. L., R. K. Morrison, R. E. Kinzer, B. G. Reeves, and R. E. Stinner. 1973. Programmed releases of parasites and predators for control of Heliothis spp. on cotton. Proc. Beltwide Cotton Res. Conf. p. 92-4.

Riley, C. V. 1883. The cabbage Plusia (Lepidoptera: Noctuidae). U. S. Dep. Agr. Annu. Rep. Comm. Agr. 1883:119-22.

Riley, C. V. 1893. Note on the life habits of Megilla maculata. Proc. Entomol. Soc. WA 2:168-70.

Roach, S. H. 1975. Heliothis zea and H. virescens: Moth activity as measured by blacklight and pheromone traps. J. Econ. Entomol. 68:17-21.

Schaffner, J. V., Jr., and C. L. Griswold. 1934. Macro-lepidoptera and their parasites reared form collections in the northeastern part of the United States. U. S. Dep. Agr. Misc. Publ. 188:69-70.

Schmidt, G. T. 1970. The effect of host development on parasitism and mortality of two pests attacked by Trichogramma evanescens (Hymenoptera: Trichogrammatidae). Ann. Entomol. Soc. Amer. 63: 1319-22.

Schuster, M. F., and J. C. Boling. 1974. Phenology of early and mid-season predaceous and phytophagous insects in cotton in the lower Rio Grande Valley of Texas. TX Agr. Exp. Sta. MP 1133. 31 p.

Semel, M. 1956. Polyhedrosis wilt of the cabbage looper on Long Island. J. Econ. Entomol. 49:420-1.

Shepard, M., G. R. Carner, and S. G. Turnipseed. 1974a. A comparison of three sampling methods for arthropods in soybeans. Environ. Entomol. 3:227-32.

Shepard, M., G. R. Carner, and S. G. Turnipseed. 1974b. Seasonal abundance of predaceous arthropods in soybeans. Environ. Entomol. 3:985-8.

Shepard, M., W. Sterling, and J. K. Walker, Jr. 1972. Abundance of beneficial arthropods on cotton genotypes. Environ. Entomol. 1: 117-21.

Shorey, H. H., L. A. Andres, and R. L. Hale. 1962. The biology of Trichoplusia ni (Lepidoptera: Noctuidae). I. Life history and behavior. Ann. Entomol. Soc. Amer. 55:591-7.

Sirrine, F. A. 1899. Spraying mixture for cauliflower and cabbageworms. NY Agr. Exp. Sta. Annu. Rep. 17:389-413.

Smith, B. C. 1960. A technique for rearing coccinellid beetles on dry food and influence of various pollens on the development of Coleomegilla maculata lengi Timb. (Coleoptera: Coccinellidae). Can. J. Zool. 38:1047-9.

Smith, C. E., and R. W. Brubaker. 1938. Observations on cabbageworm populations at Baton Rouge, Louisiana. J. Econ. Entomol. 31: 697-700.

Smith, R. F., and H. T. Reynolds. 1972. Effects of manipulation of cotton agro-ecosystems on insect populations. In M. T. Favar and J. P. Milton, ed:, The careless technology: Ecology and international development. NY Natural History Press.

Smith, R. F., and R. van den Bosch. 1967. Integrated control. p. 295-340. In W. W. Kilgore and R. L. Doutt, ed., Pest control: Biological, physical and selected chemical methods. Academic Press, New York, NY.

Snow, J. W., and J. R. Brazzel. 1965. Seasonal host activity of the bollworm during 1963 in northeast Mississippi. MS Agr. Exp. Sta. Bull. 712. 23 p.

Snow, J. W., and R. L. Burton. 1967. Seasonal occurrence of the Heliothis complex on Desmodium purpureum with observations on parasitism by Cardiochiles nigriceps. J. GA Entomol. Soc. 47-52.

Snow, J. W., J. J. Hamm, and J. R. Brazzel. 1966. Geranium carolinianum as an early host for Heliothis zea and H. virescens (Lepidoptera: Noctuidae) in the southeastern United States, with notes on associated parasites. Ann. Entomol. Soc. Amer. 59:506-9.

Soo Hoo, C. F., R. S. Seay, and P. V. Vail. 1974. Voria ruralis: Field cage evaluation of four densities of the larval parasite against Trichoplusia ni. Environ. Entomol. 3:439-40.

Southwood, T. R. E., and M. J. Way. 1970. Ecological background to pest management. p. 6-25. In R. L. Rabb, and F. E. Guthrie, ed., Concepts of pest management. NC State Univ., Raleigh, NC.

Staten, R. T. 1970. The bionomics and entomophagous vector capabilities of Geocoris punctipes Say. Ph.D. thesis. Univ. of CA, Riverside, CA. 122 p.

Stern, V. M., and H. H. Shorey. 1968. Biological notes on, and eradication of Trichogramma semifumatum for laboratory cultures of eight species of Noctuidae. J. Econ. Entomol. 61:898-901.

Stewart, J. W., W. H. Whitcomb, and K. O. Bell. 1967. Estivation studies of the convergent lady beetle in Arkansas. J. Econ. Entomol. 60:1730-5.

Stinner, R. E., R. L. Rabb, and J. R. Bradley. 1974a. Population dynamics of Heliothis zea (Boddie) and H. virescens (F.) in North Carolina: A simulation model. Environ. Entomol. 3:163-8.

Stinner, R. E., R. L. Ridgway, J. R. Coppedge, R. K. Morrison, and W. A. Dickerson, Jr. 1974b. Parasitism of Heliothis eggs after field releases of Trichogramma pretiosum in cotton. Environ. Entomol. 3:497-500.

Stinner, R. E., R. L. Ridgway, and R. E. Kinzer. 1974c. Storage, manipulation of emergence, and estimation of numbers of Trichogramma pretiosum. Environ. Entomol. 3:505-7.

Stinner, R. E., R. L. Ridgway, and R. K. Morrison. 1974d. Longevity, fecundity, and searching ability of Trichogramma pretiosum reared by three methods. Environ. Entomol. 3:558-60.

Sutherland, D. W. S. 1965. Biological investigations of Trichoplusia ni (Hubner) and related and associated species damaging cruciferous crops on Long Island, N. Y. 1960-63. Ph.D. thesis. Cornell Univ., Ithaca, NY. 387 p.

Sutherland, D. W. S. 1965. Biolcgical investigations of Trichoplusia ni (Hubner) and other Lepidoptera damaging cruciferous crops on Long Island, N. Y. NY State Exp. Sta. Mem. 399. 99 p.

Sweetman, H. L. 1936. The biological control of insects. Comstock Publishing Co., Ithaca, NY. 461 p.

Szumkowski, W. 1952a. Observations of Coccinellidae. I. Coccinellids as predators of lepidopterous eggs and larvae in Venezuela. Trans. 9th Inter. Congr. Entomol. 1:778-81.

Szumkowski, W. 1952b. Observations on Coccinellidae. II. Experimental rearing of Coleomegilla on a non-insect diet. Trans. 9th Inter. Congr. Entomol. 1:781-5.

Tanabe, A. M., and M. Tamashiro. 1967. The biology and pathogenicity of a microporidian (Nosema trichoplusiae sp. n.) of the cabbage looper, Trichoplusia ni (Hubner) (Lepodoptera: Noctuidae). J. Invert. Pathol. 9:188-95.

Tauber, C. A. 1974. Systematics of North American chrysopid larvae: Chrysopa carnea group (Neuroptera). Can. Entomol. 106:1133-53.

Taylor, T. A., and V. M. Stern. 1971. Most preference studies with the egg parasite Trichogramma semifumatum (Hymenoptera: Trichogrammatidae). Ann. Entomol. Soc. Amer. 64:1381-99.

Teetes, G. L., N. M. Randolph, and M. L. Kinman. 1970. Notes on noctuid larvae attacking cultivated sunflowers. J. Econ. Entomol. 63: 1031-2.

Teitz, H. M. 1972. An index to the described life histories, early stages, and hosts of the macrolepidoptera of the continental United States and Canada. A. C. Allyn, Allyn Museum of Entomol., Sarasota, FL. 1041 p.

Thomas, G. M., and G. O. Poinar, Jr. 1973. Report of diagnoses of diseased insects 1962-1972. Hilgardia 42:261-359.

Thomas, W. A. 1945. Cyrtopeltis varians in some of the tobacco-growing areas of North Carolina. J. Econ. Entomol. 38:498-9.

Tugwell, P., E. P. Rouse, and R. G. Thompson. 1973. Insects in soybeans and a weed host (Desmodium sp.). AK Agr. Exp. Sta. Rep. Ser. 214. 18 p.

Turnipseed, S. G. 1972. Management of insect pests of soybeans. Proc. Tall Timbers Conf. Ecol. Control Habitat Management 4:189-203.

Vail, R. V., T. Miller, and I. M. Hall. 1967. A cytoplasmic polyhedrosis of the cabbage looper, Trichoplusia ni. J. Invert. Pathol. 8:430-41.

van den Bosch, R., and K. S. Hagen. 1966. Predaceous and parasitic arthropods in California cotton fields. CA Univ. Agr. Exp. Sta. Bull. 820. 32 p.

van den Bosch, R., T. F. Leigh, L. A. Falcon, V. M. Stern, D. Gonzales, and K. S. Hagen. 1971. The developing program of integrated control of cotton pests in California. In C. B. Huffaker, ed., Biological control. Plenum Press, New York, NY.

van den Bosch, R., and P. S. Messenger. 1973. Biological control. Intext Educational Publishers, New York, NY. 180 p.

Vanderzant, E. S. 1969. An artificial diet and a rearing method for Chrysopa carnes larvae and adults. J. Econ. Entomol. 62:256-7.

van Steenwyk, R. A., N. C. Toscano, G. R. Ballmer, K. Kido, and H. T. Reynolds. 1975. Increases of Heliothis spp. in cotton under various insecticide treatment regimes. Environ. Entomol. 4: 993-6.

Waddill, V., and M. Shepard. 1974. Biology of a predaceous stinkbug, Stiretsus anchorago (Hemiptera: Pentatomidae). FL Entomol. 57: 249-53.

Wall, R., and R. C. Benbenet. 1975. Parasitoids associated with lepidopterous pests on peanuts; Oklahoma fauna. Environ. Entomol. 4:877-82.

Watson, T. F., R. T. Gudauskas, and T. D. Canerday. 1966. Parasites, pathogens, and predators of some lepidopterous pest in Alabama. Auburn Univ. Agr. Exp. Sta. Zool. Entomol. Dep. Ser. 1. 3 p.

Watt, K. E. F. 1965. Community stability and the strategy of biological control. Can. Entomol. 97:687-95.

Webster, F. M. 1880. Food habits of ground beetles. Amer. Entomol. 3:173.

Weires, R. W., and H. C. Chiang. 1973. Integrated control prospects of major cabbage insect pests in Minnesota based on the faunistic, host varietal, and trophic relationships. Agr. Exp. Sta. Univ. MN Tech. Bull. 291. 42 p.

Wene, G. 1943. Sagaritis provanchori (Dalla Torre), an important parasite of the tobacco budworm. J. Econ. Entomol. 36-333-4.

West, L. S. 1925. Phasiidae and tachinidae of New York and adjacent states. Ph.D. thesis. Cornell Univ., Ithaca, NY. 237 p.

Whitcomb, W. H. 1974. Natural populations of entomophagous arthropods and their effect on the agroecosystem. In F. G. Maxwell, and F. A. Harris, ed., Proceedings of the summer institute on biological control of plant insects and diseases. Univ. Press of MS, Jackson, MS.

Whitcomb, W. H., and K. Bell. 1964. Predaceous insects, spiders, and mites of Arkansas cotton fields. Univ. AK Agr. Exp. Sta. Bull. 690. 84 p.

Whitcomb, W. H., H. A. Denmark, A. P. Bhatkar, and G. L. Greene. 1972. Preliminary studies on the ants of Florida soybean fields. FL Entomol. 55:129-42.

Wille, J. E. 1951. Biological control of certain cotton insects and the application of new organic insecticides in Peru. J. Econ. Entomol. 44:13-8.

Wilson, F. 1966. The conservation and augmentation of natural enemies. Proc. FAO Symp. Integrated Pest Control. 3:21-6.

Wilson, J. W. 1956. Abundance of aphids and caterpillars in commercial cabbage fields in the vicinity of Sanford, Florida. FL Entomol. 40:95-101.

Wolfenbarger, D. A. 1967. Seasonal abundance and damage estimates of cabbage looper larvae and two aphid species. J. Econ. Entomol. 60:277-9.

Yendol, W. G., and J. P. Paschke. 1967. Infection of a looper complex by Entomophthora sphaerosperma. J. Invert. Pathol. 9:274-6.

Zelier, P. C. 1869. Observations on Plusia ni. Entomol. Mo. Mag. 6:12-3.

APPENDICES

APPENDIX A

Predaceous Hemiptera
in an 8-acre cropping system.

Species	Crops collected from[a]	Months collected in[a]	Remarks
	Lygaeidae		
Geocoris punctipes (Say)	All crops	All months	Common and abundant
G. uliginosus (Say)	Bahia grass, white clover[b]	September-December	Not common
	Nabidae		
Nabis capsiformis Germar	Most crops	Most months	Common
Nabis roseipennis Reuter	Most crops	Most months	Common
Nabis deceptivus Harris	Sorghum	June	Rare
	Anthocoridae		
Orius insidiosus (Say)	Most crops	April-January	Common, and abundant in some crops
Cardiastethus assimilis (Reuter)	Soybeans, collards, sorghum, bush beans	August, September	Common late in the soybean-growing season
Lasiochilus hirtellus Drake & Harris[c]	White clover, soybeans	January, August	Rare
Xylocoris sordidus (Reuter)[c]	Soybeans	August	Rare
	Pentatomidae		
Podisus maculiventris (Say)	Soybeans, field corn, sweet corn, sorghum, okra, tomatoes field peas, bell peppers	May-October	Common but not abundant
Stiretrus anchorago (F.)[d]	Soybeans, field corn	August	Not common
Alcaeorrhynchus grandis (Dallas)	Soybeans	August	Rare
	Reduviidae		
Zelus cervicalis Stal	Soybeans, okra, peanuts, field peas, bell peppers, wheat, bahia grass, wild hosts	February, May-September	Common but not abundant
Atrachelus cinereus (F.)	Okra, clover, collards	June-August	
Sirea spinipes (Herrich-Schaeffer)	Flue-cured tobacco, sweet corn, field corn, peanuts, wild hosts	July	Common but not abundant
	Berytidae		
Jalysus spinosus (Say)	Flue-cured tobacco, cigar-wrapper tobacco, white clover, tomatoes, sweet corn	June-September	Not common
Acanthus multispinus[c] (Ashmead)	Okra	June	Rare
	Miridae		
Sparagonicus albofasciatus (Reuter)	Most crops	January, May-August	Common and often abundant
Dicyphus minimus (Uhler)[e] (=Cyrtopeltis notatus Distant)	Flue-cured tobacco, cigar-wrapper tobacco, tomatoes	August, September	Numerous on tobacco and tomatoes in late summer and early fall.

[a]Determinations were made from "representative" samples from D-vac collections; some may have been collected in other crops and months.

[b]Also in crabgrass, and between rows in bell peppers.

[c]Not established as a predator of eggs and larvae of Lepidoptera.

[d]Mostly a predator of Mexican bean beetles.

[e]Thomas (1945) and Elsey (1972) reported Cyrtopeltis varians (Distant) preying on eggs and 1st-instar larvae of Heliothis spp. in tobacco.

APPENDIX B

Seasonal abundance and species composition of Chrysopa in crops in an 8-acre cropping system from December, 1971-August, 1973.

Month[a]	Collards	Soybeans	Flue-cured tobacco	Cigar-wrapper tobacco	Okra	White clover	Tomatoes	Sweet corn	Field corn	Sorghum	Millet	Field peas	Bell peppers	Squash	Total
							Chrysopa rufilabris Burmeister[b]								
Feb.															1
Mar.	3					1									4
Apr.	5					1									7
May	31	6				1	5	4	2		1		6		64
Jun.	5	68		1	10		10	7	5			5	2		113
Jul.	2	34		5	22	2	3	4	7	10	1[c]	4	2		97
Aug.		31			7			2		4		13			57
Sep.		22								1					24
Oct.							4			1	1[c]	8	1	11	25
Nov.													1		1
Total	47	161	0	6	39	5	22	17	14	16	3	30	12	11	404[d]
							Chrysopa cubana Hagen								
Jul.										2					2
Aug.								1		4		5			10
Sep.											2	5			7
Oct.										1					1
Total	0	0	0	0	0	0	0	1	0	7	2	10	0	0	20
							Chrysopa oculata Say[e]								
Apr.	1														1
May	2														2
Jun.		1	1	1			1								5
Jul.					3										3
Oct.	7														7
Nov.															1
Total	10	1	1	1	3	0	1	0	0	0	0	0	0	0	20
							Chrysopa externa Hagen								
May								1							1
Jun.		1											1		2
Aug.								1	1						2
Sep.		1				1				1					3
Oct.								1		3				1	5
Nov.									1[c]						1
Total	0	2	0	0	0	1	0	3	2	4	0	0	1	1	16[d]

Note: Specimens were identified by Catherine Tauber (Dep. of Entomol., Cornell Univ., Ithaca, NY) from collections from whole plant inspections, sweeps, and O-vac samples in the 8-acre system.

[a]One *Chrysopa carnea* Stephens was found in rye on April 2, 1973 and 1 during March, 1973. One *C. nigricornis* was found in collards in May, 1973, and 1 *C. lineaticornis* Fitch was found on soybeans September 1, 1973.

[b]*C. rufilabris* were also found in cabbage in May (1), rye in February (1), crimson clover in April (2) and May (4), and other wild hosts in July (1).

[c]Determined as probably *C. rufilabris* and *C. externa*, respectively.

[d]Eleven *C. rufilabris* and 2 *C. externa* were unlabeled but were caught in the 8-acre system.

[e]*C. oculata* were also found in bahia grass in June (1) and wild hosts in November (1).

APPENDIX C

Seasonal abundance and species composition of Microrus in crops in an 8-acre cropping system from December, 1971-August, 1973.

Month	Rye	Wheat	White clover	Collards	Cigar-wrapper tobacco	Sorghum	Bell peppers	Sweet corn	Field corn	Field peas	Bahia grass	Wild hosts	Total
						Micromus subanticus Walker							
Jan.	17	18									1	2	38
Feb.		42	1	2									45
Mar.	6	7										1	14
Apr.		3	2					1			6		12
May			5								10		15
Jun.			1	1	1				5			1	9
Jul.			15				6	1			1		23
Dec.											3[a]		3
Total	23	70	25	3	1	0	6	2	5	0	21	4	170[b]
						Micromus posticus Walker							
Jan.	13	2										1	16
Feb.		3											3
Mar.	1												1
Apr.				4				1					5
May													0
Jun.					14								14
Jul.			1			6	3	1					11
Oct.				1		1							1
Total	14	5	1	5	14	7	3	2	0	0	0	1	54[b]
						Micromus spp.							
Mar.	9												9
Apr.		1	7								9		17
May	37	1	3								12		53
Jul.			6		5	1							12
Sep.										2			2
Total	46	2	16	0	5	1	0	0	0	2	21	0	93

Note: Most specimens identified were collected from D-vac samples, whole plant inspections, and sweeps.

[a]These were collected in December 1971.

[b]Ten M. subanticus and 2 M. posticus were unlabeled, but were caught in the 8-acre system.

APPENDIX D

Relative abundance of ants in crops in an 8-acre cropping system.

	Row crops						Mostly broadcasted[a]	Broadcasted		Soils not disturbed during study	
Month	Tobacco[b]	Soybeans	Corn[c]	Okra	Crucifers[d]	Others[e]	Sorghum and Millet	Rye and wheat	White clover	Bahia grass	Wild hosts
					Ca. no./acre						
1971-72											
Dec.					0			60		20970	
Jan.					1230			0	0	2650	3630
Feb.					0			10	0	6080	2180
Mar.					0	0		0	0	1760	2570
Apr.	0		0		0	0		0	0	1440	500
May	0		0		0	0	0		0	3440	340
Jun.	0	10	10	0	0	0	0		40	6240	20
Jul.	0	0	20	0	0	90	0		220	5840	20
Aug.	0	0	0	20	-	10	20		440	11860	5960
Sep.		10	100	150	-	10	10		160	6710	1420
Oct.					0	30	0		10	4360	6370
Nov.					0	0	0		170	420	960
Dec.					0	100		100	0	2330	440
1973											
Jan.						30		60	0	220	140
Feb.						0		0	0	430	230
Mar.						0		0	70	70	630
Apr.	0					0	10	0	60	590	430
May	0	0	0	0		0	0		0	660	340
Jun.	0	0	0	130		0	0		0	680	330
Jul.	0	0	0	0		0			0	1050	0
Aug.				80							
$\bar{x}$	0	<10	<10	20		20	<10	30	60	3890	1390

Note: Weekly estimates were averaged to obtain these means. Data were from D-vac samples of ca. 0.03 acre.

[a] Sorghum was rowed in 1972.

[b] Flue-cured cigar-wrapper tobacco.

[c] Sweet corn and field corn.

[d] Collards and cabbage.

[e] Southern field peas, peanuts, bell peppers, tomatoes, turnips, pumpkins, bush beans, and squash.

APPENDIX E

Seasonal abundance of *Geocoris* spp. in crops in an 8-acre cropping system.

Date (week of)	Collards	Cabbage	White clover	Soybeans[a]	Tobacco[b]	Okra	Rye and wheat	Corn[c]	Sorghum	Field peas and peanuts	Other crops[d]	Kehia grass and wild hosts[e]
1971-72							Ca./no./acre					
Dec. 5	0						-f					70
12	0											100
19	0											-
26	0											170
Jan. 2	0											0
9	0											-
16	0											50
23	0						-g					690
30	0		-f				-g					100
Feb. 6	0		-f				-f					40
13	0		-f				-f					-
20	0		-f				-f					0
27	0		-f				-					-
Mar. 5	0		-f				-f					0
12	0	0	-f				-f					0
19	0	0	-f				-					20
26	0	0	-f				-f					-
Apr. 2	0	0	0				-f					-
9	0	0	0		0		-g				0	-
16	0	0	0g		0		-g	0	0		0	0
23	0	0	0		0		-g	0	0		0	100
30	0	0	1330		0			0	0		0	20
May 7	0	0	0		0			0	0		0	40
14	0	0	8690		0			250	0		0	200
21	0	0	1330		160			340	0		0	-
28	0		0g		0			340	830	0	0	-
Jun. 4	0		1330	80	160	0		340	0	0	0	360
11	0		2670	0	170	170		500	670	0	0	-
18	0		-g	250	170	0		580	170	0	0	-
25	0		4670	80	170	0		460	0	0	0	500
Jul. 2	0		-g	670	800	-		420	1170	0	0	4625
9	0		660	1500	0	2160		2780	-	0	0	690
16	0		1660	1410	340	0		3660	670	160	500	1020
23	0		4680	1500	420	840		2250	2000	840	420	220
30			1200	3600	0	4000		4020	1330	240	340	-
Aug. 6			16000	3660	0	2670		13740	4000	3840	300	30
13	0		27320	3580		250		6470	1670	3390	1660	140
20	0		18680	7340		160		5500	7040	3000	2170	-
27	0		3340	1330		960		4580	12840	7360	2340	130
Sep. 3	0		-	2330		830		5330	4500	670	1880	40
10	0		-g	6580	-hi	2170			3500	670	14160	80
17	0		0g	10000	-hi	330			1000	0	1170	100
24	0		-	4670	-hj	0			2170	660	835	-
Oct. 1	0		-g	-	-hi	1000			1000	330	0	100
8	0		-g	-	-hi	670			1000	0	40	130
15	0		-	-	-hj	1000			0	420	50	-
22	0		-g	-	-hi	0			1000	0	1250	-
29	170		-g	330	-hi	0			0	0	500	-

Nov.	5	0		680					3170	500	840	-
	12	0		680				0			1000	150
	19	0		4000				0[g]			0	130
	26	0		-[g]				0			670	980
Dec.	3	0		6680				0[g]			670	1070
	10	0		4000				0[g]			0	720
	17	0		5320				680			0	-
	24	-		7320				4660			500	-
	31	410		-[g]				680			500	-
1973												
Jan.	7	0		-[f]				0			0	0
	14	1250		1320				0			1670	0
	21	0		0				0			0	0
	28	0		680				1000				-
Feb.	4	210		-				0[g]				0
	11	210		0				0[g]				0
	18	210		0[g]				0[g]				-
	25	0		2000				-[f]				0
Mar.	4	0		1000				-[g]				0
	11	0		2680				680				-
	18	0		680				340				-
	25	0	0	680		0		0[g]				0
Apr.	1	210	0	1320		0		0				0
	8	0	0	1320		0		-[f]			0	0
	15	0	0	0[g]		0		-[f]			0	0
	22	0	0	-		0			0	0	0	0
	29	0	0	-		0			0	0	0	0
May	6	0	0	1320		0			0	0	0	20
	13	0	0	1320		0			0	-[f]	0	40
	20	0	0	1320	0	0	0		0	0	160	60	40
	27	210	0	0[g]	0	0	670		0	0	80	60	140
Jun.	3	0	-	-[g]	0	0	1330		670	-[g]	0	420	0
	10	0	0	-[g]	0	0	0		0	1330	500	0	250
	17	0		4000	1170	0	170		3000	-[f]	160	110	50
	24	0		680	170	0	-		670	0	250	170	220
Jul.	1	0		2640	2500	330	920		6670	660	670	1056	360
	8	0		0	4670	0	4170		6660	-	2000	500	20
	15	200		5320	5250	140	-		-	0	2840	1080	
	22			-[g]	5250		1920		1000	0	5340	450	
	29			6680	8250		2830		0	0	1420	1500	
Aug.	5			-[g]	3170		0						
	12			-[g]	3000		3000					-[f]	

Note: Estimates were from inspections of whole plants made once or twice weekly on ca. 0.002-0.006 acre.

[a]Some estimates were from shake samples of 0.006 acre.

[b]Flue-cured and cigar-wrapper tobacco.

[c]Sweet and field corn.

[d]Including tomatoes, turnips, millet, squash, bell peppers, bush beans, and pumpkins.

[e]Estimates were from D-vac samples of ca. 0.03 acre weekly.

[f]Sweeps yielded no Geocoris spp.

[g]Seventy-five to 150 sweeps with a 15 in. net yielded 0.3-53.0 per 100 sweeps.

[h]From a sparse stand of volunteer tobacco.

[i]Counts/100 tobacco plants ranged from 1.7-26.7.

[j]Counts/100 plants yielded no Geocoris spp.

APPENDIX F

Relative and seasonal abundance of selected predaceous arthropods in rye.

Date (Week of)	1. Geocoris	2. Nabis	3. Orius	4. Chrysopa	5. Coleomegilla	6. Hippodamia	7. Lady beetle larvae	8. Scymnus	9. Ground beetles	10. Earwigs	11. Other predators	12. Spiders
1972												
Dec. 5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.1	0.1
12	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
26	0.0	0.2	0.0	<0.1	0.0	0.0	0.0	0.0		0.0	0.0	0.1
Jan. 2	0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
16	0.1	0.5	<0.1	0.0	0.0	0.0	0.0	0.0		0.0	0.6	0.4
23	0.1	0.4	0.1	0.0	0.0	0.0	0.0	0.0		0.0	0.4	0.4
30	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.4	0.7
Feb. 6	<0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.2	0.3
13	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.8	0.7
20	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.5	0.6
27	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.1	None	0.0	0.5	0.3
Mar. 12	0.0	0.4	0.0	<0.1	0.0	0.0	0.0	0.0	found	0.0	0.1	0.2
Apr. 2	0.0	0.3	0.0	0.0	0.0	<0.1	<0.1	0.0		0.0	0.0	<0.1
9	0.0	0.3	0.0	0.0	<0.1	<0.1	1.1	0.0		0.0	0.0	0.1
Nov. 12-26[b]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
Dec. 3	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.7
10	<0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.1	0.1
17[a]	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
24	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0		0.0	<0.1	0.1
31	<0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	<0.1
1973												
Jan. 7	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	<0.1
14	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.2
21	0.0	0.2	0.0	0.0	0.0	<0.1	0.0	0.0		0.0	0.0	0.0
28	0.1	0.0	0.0	0.1	0.0	0.0	0.0	<0.1		0.0	0.2	0.3
Feb. 4	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0		0.0	0.2	0.1
11	0.0	0.0	<0.1	<0.1	0.0	0.0	0.0	0.0		0.0	0.0	0.0
18	0.0	<0.1	0.0	<0.1	0.0	0.0	<0.1	0.0	None	0.0	0.0	0.3
25	0.0	0.1	0.0	<0.1	0.0	0.0	0.0	0.0	found	0.0	0.0	0.1
Mar. 4	0.0	0.1	0.0	<0.1	0.0	0.0	0.0	0.0		0.0	0.0	0.0
11[a]	0.7	0.7	0.0	-	0.0	0.0	0.0	0.0		0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
Apr. 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	<0.1
15	0.0	0.1	0.0	0.0	0.0	<0.1	0.1	0.0		<0.1	0.1	0.1

Note: The numbered columns represent the following predators: adults and immatures of (1) Geocoris spp. (mostly Geocoris punctipes), (2) Nabis spp., (3) Orius insidiosus, and (4) Chrysopa spp. rufilabris); adults of (5) Coleomegilla maculata and (6) Hippodamia convergens; (7) immatures of the large Coccinellidae; (8) adults of the small Coccinellidae; adults and immatures of (9) Carabidae and (10) Dermaptera; (11) other predaceous insects including adults and immatures of Podisus maculiventris, Jalysus spinosus, Reduviidae, and Hemerobiidae, and adults of Notoxus spp.; and (12) adults and immatures of Araneida. None were found if columns are absent. Estimates were generally from weekly D-vac samples of 0.03 acre.

[a]Data were from weekly inspections of whole plants on ca. 0.003-0.006 acre.

[b]Samples were taken during the weeks of November 12, 19, and 26.

APPENDIX G

Relative and seasonal abundance of selected predaceous arthropods in wheat.

Date (week of)	1. Geocoris	2. Nabis	3. Orius	4. Chrysopa	5. Coleomegilla	6. Hippodamia	7. Lady beetle larvae	8. Scymnus	9. Ground beetles	10. Earwigs	11. Other predators	12. Spiders
					Ca. no./acre							
1972												
Dec. 5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
12	0.0	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.1
Jan. 2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.1	0.2
16	0.1	0.5	0.0	<0.1	0.0	0.0	0.0	0.0	0.0		1.2	0.1
23	0.2	0.4	<0.1	0.0	0.0	0.0	0.0	0.0	0.0		1.0	0.5
30	0.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1.7	0.3
Feb. 6	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.2	0.0
13	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.8	<0.1
20	0.7	0.5	0.0	0.0	<0.1	0.0	0.0	0.1	0.0	None	0.9	0.7
27	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	found	0.5	0.7
Mar. 5	0.1	0.1	0.0	0.1	0.0	<0.1	0.0	0.0	0.0		0.2	0.3
12	0.2	1.0	0.0	0.0	0.1	0.0	0.0	0.4	0.2		0.2	0.6
26	0.0	0.5	0.0	0.0	<0.1	0.0	0.0	0.0	0.0		0.0	0.3
Apr. 2	0.0	<0.1	0.0	0.0	0.0	0.0	<0.1	0.0	0.0		0.0	0.2
9	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0		0.0	0.1
16	0.0	0.3	0.0	0.0	0.0	0.0	1.0	0.0	0.0		0.2	0.1
23	0.0	0.2	0.0	0.0	0.0	0.0	0.6	0.0	0.0		0.0	0.1
Nov. 12-26[b]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
Dec. 3	0.6	<0.1	<0.1	0.0	0.0	<0.1	0.0	0.1	0.0		0.1	0.4
10	<0.1	0.1	0.0	0.0	0.0	0.0	0.0	<0.1	0.0		0.1	<0.1
17[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
24	<0.1	<0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0		0.1	0.1
31	<0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0		<0.1	0.1
1973												
Jan. 7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.1	0.0
14	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.2	0.1
21	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.0		0.2	1.5
28	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.4	0.5
Feb. 4	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.1	0.1
11	<0.1	0.0	0.0	0.0	0.0	<0.1	0.0	0.0	0.0	None	0.0	0.1
18	<0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	found	0.0	0.3
25	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.1	0.1
Mar. 4	0.0	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	<0.1
11	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.1	0.2
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.1
Apr. 1	0.0	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0		<0.1	0.0

Note: The numbered columns represent the following predators: adults and immatures of (1) Geocoris spp. (mostly Geocoris punctipes), (2) Nabis spp., (3) Orius insidiosus, and (4) Chrysopa spp. (mostly C. rufilabris); adults of (5) Coleomegilla maculata and (6) Hippodamia convergens; (7) immatures of the large Coccinellidae; (8) adults of the small Coccinellidae; adults and immatures of (9) Carabidae and (10) Dermaptera; (11) other predaceous insects including adults and immatures of Podisus maculiventris, Galysus spinosus, Reduviidae, and Hemerobiidae, and adults of Notoxus spp.; and (12) adults and immatures of Araneida. None were found if columns are absent. Estimates were generally from weekly D-vac samples of 0.03 acre.

[a]Data were from weekly inspections of whole plants on ca. 0.003-0.006 acre.

[b]Samples were taken during the weeks of November 12, 19 and 26.

APPENDIX H

Relative and seasonal abundance of selected predaceous arthropods in sweet corn, field corn, sorghum, and millet.

Date (Week of)	1. Geocoris	2. Nabis	3. Orius	4. Chrysopa	5. Coleomegilla	6. Hippodamia	7. Lady beetle larvae	8. Scymnus	9. Ground beetles	10. Earwigs	11. Other predators	12. Spiders
					Ca. no./acre							
					Sweet corn[a]							
1972												
Apr. 16	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.2	0.5	0.0	0.0	0.0	0.0	
23	0.0	0.1	0.0(0.0)	0.0(0.0)	1.2	0.7	0.4	0.0	0.0	0.0	0.0	1.5
30	0.0	0.5	0.0(0.0)	1.3(0.0)	1.0	1.3	1.7	0.0	0.0	0.0	0.0	1.7
May 7	0.7	0.4	0.2(-)	0.2(-)	2.7	1.1	0.3	0.0	0.1	0.0	0.0	0.2
14	0.7	0.3	0.0(2.5)	1.0(0.1)	4.5	2.3	1.7	0.0	0.0	0.0	0.0	1.7
21	0.7	0.7	0.0(1.2)	5.0(0.0)	3.0	3.8	1.5	0.0	0.0	0.5	0.0	2.0
28	0.7	0.3	0.2(3.0)	1.0(0.1)	3.0	1.5	2.3	1.3	0.0	0.0	0.0	0.0
Jun. 4	1.0	0.7	0.3(3.3)	5.2(0.1)	4.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0
11	1.2	0.9	1.8(2.1)	0.1(0.1)	3.1	1.5	2.8	0.4	0.0	0.3	0.1	0.4
18	0.9	3.1	18.8(3.0)	0.1(0.1)	4.8	1.8	2.8	0.0	0.0	0.0	0.5	0.0
25	0.8	0.0	0.0(0.7)	7.8(0.0)	0.5	0.3	0.2	0.0	0.0	0.0	0.0	0.3
Jul. 2	4.7	0.0	1.4(0.5)	2.3(0.1)	0.0	0.0	0.0	0.0	0.7	0.1	0.1	0.7
9	0.7	0.0	0.0(0.5)	0.0(0.0)	1.0	0.7	1.1	0.0	0.0	0.2	0.0	0.7
16	4.5	0.0	6.7(1.2)	0.5(0.1)	1.5	1.5	1.5	0.5	0.7	1.0	0.3	1.7
23	0.0	0.0	0.0(1.4)	1.0(0.1)	1.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0
30	6.7	0.0	5.3(1.1)	0.0(0.1)	0.0	7.3	9.1	0.0	0.0	10.4	0.0	0.0
Aug. 6	6.5	0.0	0.0(0.3)	2.3(0.0)	0.0	1.3	1.8	0.0	0.0	3.8	0.0	0.0
13	5.5	0.0	0.0(1.2)	0.0(0.0)	1.3	0.0	1.0	0.0	0.5	5.8	0.0	0.0
20	4.6	0.2	0.0(0.1)	0.6(0.1)	1.7	0.7	3.2	0.2	1.3	6.5	0.0	0.0
27[b]	5.3	0.0	0.0(-)	0.0(-)	2.0	0.3	1.0	0.0	0.0	7.3	0.0	0.0
Sep. 3	1.9	0.4	0.3	0.3	0.1	0.4	0.1	<0.1	0.1	0.4	0.5	0.0
					Field corn							
1972												
May 7	0.0	0.0	0.0(0.0)	0.0(0.0)	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.5
14	0.0	0.0	0.0(0.0)	0.0(0.0)	2.8	0.8	0.0	0.2	0.0	0.0	0.0	0.1
21	0.0	0.0	0.0(0.1)	0.0(0.0)	1.0	1.0	0.2	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0(1.1)	0.0(3.0)	3.3	0.9	0.0	0.0	0.0	0.5	0.0	0.3
Jun. 4	0.0	0.0	0.0(1.0)	0.0(0.0)	3.2	1.3	2.5	0.0	0.0	0.2	0.0	0.6
11	0.0	0.0	4.3(0.5)	0.0(0.0)	2.0	1.8	0.0	0.0	0.0	0.0	0.0	0.3
18	0.0	0.0	30.0(1.6)	0.9(0.0)	6.0	1.5	1.5	0.0	0.0	1.0	0.0	1.0
25	0.0	0.0	0.0(0.5)	0.0(0.1)	1.3	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Jul. 2	0.9	0.2	1.1(0.4)	0.0(0.1)	1.0	1.2	0.8	0.0	0.0	0.8	0.0	0.0
9	6.7	0.2	25.3(0.4)	0.0(0.0)	4.0	2.0	1.3	0.0	0.5	2.0	0.2	1.3
16	0.0	0.0	0.0(0.6)	0.0(0.1)	1.3	0.2	0.0	0.0	0.0	0.5	0.0	0.0
23	8.0	0.0	0.0(0.0)	0.0(0.1)	0.3	0.0	0.1	0.0	0.0	5.5	0.0	1.6
30	10.8	0.0	0.0(0.1)	0.0(0.0)	1.0	0.2	0.0	0.2	0.2	5.2	0.0	0.0
Aug. 6	6.4	0.1	0.0(0.0)	0.6(0.1)	0.2	1.5	0.5	0.1	0.0	5.4	0.1	0.3
1973												
May 6[c]	0.0	0.0	0.0(0.0)	0.0(0.0)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0(0.0)	0.0(0.0)	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	1.0(0.0)	0.0(0.0)	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.3
27	0.0	0.0	0.0(0.0)	0.2(0.0)	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0
Jun. 3	0.7	0.0	13.3(0.4)	0.0(0.0)	0.0	0.0	0.0	0.7	1.0	1.3	1.3	2.0
10	0.0	0.0	1.0(-)	0.0(-)	0.7	0.0	0.0	0.0	0.3	0.0	0.0	0.7
17	3.0	0.0	13.3(0.2)	0.0(0.0)	1.3	0.2	1.2	0.3	0.0	9.0	0.2	2.7
24	0.7	0.0	8.3(0.2)	0.2(0.3)	0.2	0.2	0.2	0.0	0.0	1.3	0.0	0.6
Jul. 1	6.7	0.0	1.0(0.2)	0.8(0.1)	0.5	0.0	1.3	0.0	0.0	18.3	0.0	4.3
8	6.7	0.0	9.2(0.5)	0.0(0.1)	0.5	0.0	0.2	0.2	0.0	7.8	0.0	0.2
29	1.0	0.0	0.0(0.0)	0.3(0.0)	0.0	0.0	0.0	0.0	0.0	4.7	0.0	0.5

APPENDIX H continued

Date (Week of)	1. Geocoris	2. Nabis	3. Orius	4. Chrysopa	5. Coleomegilla	6. Hippodamia	7. Lady beetle larvae	8. Scymnus	9. Ground beetles	10. Earwigs	11. Other predators	12. Spiders
						Ca. no./acre						
						Sorghum[a]						
1972												
Apr. 16	0.0	0.0	0.0(0.0)	0.0(0.0)	1.0	0.2	0.0	0.0	0.0	0.0	0.1	0.0
23	0.0	0.0	0.0(0.0)	0.0(0.0)	0.3	0.5	4.2	0.5	0.0	0.0	0.0	0.4
30	0.0	0.4	0.0(0.0)	0.0(0.0)	1.8	0.0	0.9	0.5	0.0	0.0	1.0	0.9
May 7	0.0	0.3	0.0(0.7)	0.2(0.0)	1.8	1.8	0.5	0.6	0.1	0.0	0.0	0.0
14	0.0	0.2	0.0(0.0)	0.0(0.0)	4.5	4.2	2.6	0.0	0.0	0.0	0.3	1.0
21	0.8	1.3	0.0(0.0)	0.0(0.0)	2.5	3.3	0.8	1.2	0.0	0.0	1.2	0.0
28	0.0	0.0	0.0(0.2)	0.0(0.0)	2.7	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Jun. 4	0.7	0.3	0.0(1.3)	0.0(0.0)	2.8	0.3	1.7	0.0	0.0	0.0	0.0	0.3
11	0.2	0.0	0.8(5.1)	0.0(0.1)	1.8	1.7	1.3	0.2	0.0	0.0	0.0	1.0
18	0.0	0.0	0.0(1.4)	0.0(0.0)	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
25	1.2	0.0	0.0(0.0)	0.0(0.0)	1.3	0.8	1.2	0.0	0.0	0.3	0.0	0.0
Jul. 9	0.7	0.7	0.0(1.3)	0.0(0.1)	0.7	0.0	0.3	0.0	0.0	0.3	0.0	1.0
16	2.0	0.1	0.0(0.2)	0.0(0.1)	0.9	0.3	0.0	0.0	0.0	3.8	0.0	1.1
23	1.3	0.0	0.0(0.4)	0.0(0.1)	1.3	0.0	0.0	0.0	0.0	0.3	0.0	0.0
30	4.6	0.0	0.0(1.9)	0.0(0.1)	9.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aug. 6	1.7	0.2	0.0(1.4)	0.0(0.1)	1.0	0.7	0.7	0.0	0.0	0.0	0.0	0.7
13	7.8	0.0	0.2(2.9)	0.0(0.1)	3.9	1.3	1.3	0.0	0.0	0.1	0.0	0.0
20	12.9	0.0	0.5(1.0)	0.0(0.0)	2.2	0.8	0.8	0.0	0.2	1.7	0.2	0.0
27	4.5	0.0	0.0(2.3)	0.0(0.1)	0.6	0.2	0.2	0.0	0.5	2.2	0.5	0.0
Sep. 3	3.5	0.0	2.3(1.1)	0.0(0.0)	0.6	0.3	0.3	0.0	0.0	7.5	0.0	0.0
10	1.0	0.2	0.0(1.5)	0.0(0.1)	0.2	0.0	0.0	0.0	0.2	4.5	0.2	2.2
17	2.2	0.2	4.3(0.9)	0.0(0.1)	0.0	0.0	0.0	0.0	0.0	0.6	0.0	1.6
24	1.0	0.0	0.0(-)	0.0(-)	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0
Oct. 1	1.0	0.0	0.0(2.8)	0.0(0.1)	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.7
8	0.0	0.0	0.0(0.4)	0.0(0.1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	1.0	0.0	0.0(0.0)	0.3(0.0)	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.3
22	0.0	0.0	0.0(-)	0.0(-)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
83	3.2	0.0	0.0(0.1)	0.0(0.1)	0.0	0.0	0.0	0.1	0.2	0.9	0.2	0.8
1973												
May 6[b]	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	<0.1	0.1	0.0	<0.1	0.0	0.0	0.0	<0.1
20	0.0	0.0	0.0	0.0	0.7	1.7	0.0	1.7	0.0	0.0	0.0	0.0
27	0.0	0.0	1.7	0.2	8.3	7.0	1.8	2.8	1.0	0.8	0.0	1.2
Jun. 10	1.3	0.0	1.7	0.0	0.3	1.3	0.3	1.0	1.0	0.0	0.0	0.3
24	0.0	0.2	2.8	0.0	1.4	1.0	0.1	0.1	0.0	0.3	0.2	0.5
Jul. 1	0.7	1.8	14.7	0.0	1.8	0.0	1.5	0.0	0.0	2.2	0.0	1.3
15	0.0	0.0	0.0	0.0	0.8	0.0	2.7	0.0	0.0	0.8	0.0	0.7
22	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.2	0.7	0.7	2.0
29	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	1.2
						Millet[b]						
1972												
Jun. 4	0.0	0.1	0.0	0.0	<0.1	0.3	0.0	0.0	<0.1	0.0	0.0	0.0
11	0.3	3.4	0.1	0.0	0.2	0.5	0.4	0.0	0.3	0.0	0.2	0.5
18	0.2	0.3	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.0	0.1
25	0.2	0.6	0.0	0.0	0.1	0.2	0.0	0.2	0.2	0.1	2.7	0.6
Jul. 2	0.8	0.4	0.0	0.0	0.1	0.0	0.0	0.2	0.2	0.1	0.5	0.5
9	1.7	0.2	0.2	0.0	0.1	0.2	0.1	0.0	0.4	0.0	0.1	0.1
16	1.0	0.1	0.0	0.0	0.1	0.4	0.1	<0.1	0.0	0.0	<0.1	0.3
23	0.6	0.1	0.0	0.0	0.0	0.7	1.9	0.0	0.2	0.4	0.2	0.1
30	2.0	0.2	0.0	0.0	0.1	0.4	0.2	0.1	0.1	0.8	0.3	0.4
Aug. 6	5.5	0.0	0.0	0.0	0.0	0.2	0.3	0.0	0.7	0.5	0.0	0.3
13	1.8	0.2	0.0	0.0	0.1	0.0	0.0	<0.1	0.1	0.1	0.2	0.1
20	0.9	0.2	0.0	0.0	0.1	<0.1	0.0	0.0	0.1	<0.1	<0.1	0.1
27	4.2	0.6	0.0	<0.1	0.5	0.1	0.7	0.0	0.3	1.6	0.7	0.9
Sep. 3	5.7	1.2	0.0	0.1	0.2	0.1	2.1	<0.1	0.4	4.4	0.3	1.3
10	1.4	0.7	<0.1	0.0	<0.1	0.0	0.1	0.0	0.1	2.0	0.1	0.2
17	0.8	0.3	0.0	0.0	0.0	0.0	<0.1	0.0	0.2	2.7	0.1	0.1
24	2.8	0.3	0.0	0.0	<0.1	0.0	0.0	0.0	<0.1	6.2	0.4	1.1
1973												
May 6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.1	0.1	<0.1	0.0	0.1	0.2	0.0	0.0	0.0	<0.1	0.0
20	<0.1	0.2	0.3	0.0	<0.1	0.0	0.2	0.3	0.0	0.0	0.6	0.0
27	0.1	0.2	0.4	0.0	0.1	0.1	0.0	0.2	0.0	0.0	0.1	0.1
Jun. 3	<0.1	0.1	0.2	0.0	0.0	0.4	0.0	0.1	<0.1	0.0	0.1	<0.1
10	0.1	0.2	0.5	0.0	0.6	0.2	0.6	0.1	0.0	<0.1	0.3	0.3
17	0.2	0.5	0.0	0.0	<0.1	<0.1	0.0	<0.1	<0.1	<0.1	<0.1	0.2
24	0.3	0.9	0.1	0.0	0.0	0.1	0.1	<0.1	<0.1	0.3	<0.1	0.3
Jul. 1	0.5	0.2	0.0	0.0	0.0	0.1	0.0	0.1	<0.1	0.1	0.0	0.1
8	0.1	<0.1	0.0	0.0	0.3	0.3	<0.1	0.0	0.0	0.1	0.1	<0.1
15	2.2	0.0	0.0	0.0	1.2	0.3	0.0	0.0	0.1	2.5	0.0	0.7
22	0.5	<0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.8	0.1	0.2
29	2.0	0.0	2.0	0.0	0.0	0.8	0.0	0.0	0.0	26.6	4.3	0.8

Note: The numbered columns represent the following predators: adults and immatures of (1) Geocoris spp. (mostly Geocoris punctipes), (2) Nabis spp., (3) Orius insidiosus, and (4) Chrysopa spp. (mostly C. rufilabris); adults of (5) Coleomegilla maculata and (6) Hippodamia convergens; (7) immatures of large Coccinellidae, (8) adults of small Coccinellidae; adults and immatures of (9) Carabidae and (10) Dermaptera; (11) other predaceous arthropods including adults of Hotoeus spp. and Nemerobiidae, and adults and immatures of Podisus maculiventris, Jalysus spinosus, and Peduv..dae; and (12) adults and immatures of Araneae. Estimates were generally from weekly inspections of whole plants on 0.002-0.005 acre. However, numbers in parenthesis were from D-vac samples of 0.01 acre.

[a]Sweet corn and sorghum were planted bi-weekly from March 23-July 31, 1972. That planting judged "most desirable" (to the majority of the insects studied) was sampled.

[b]Data were from weekly D-vac samples of 0.03 acre.

[c]During the weeks of April 26 and 29, none of the selected predaceous arthropods were found.

BIOGRAPHICAL SKETCH

Paul Bain Martin

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Education. Graduated from Devine High School, Devine, TX, 1964; attended Texas A&M Univ., College Station, TX, 1964-65; attended San Antonio College, San Antonio, TX, 1965-66; received B.S. degree, Jan. 1969, and M.S. degree, Aug. 1971, from Texas A&M Univ. with a major in entomology; attended Florida State Univ., Tallahassee, FL, 1972-73; attended Univ. of Florida, Gainesville, FL, 1973-76, with a major in entomology.

Work Experience. Entomologist and fieldman, Peggie Martin and Assoc., Inc., Pearsall, TX, 1975-76; graduate research assistant, Univ. of Florida, 1973-75; associate in entomology, Agr. Res. and Educ. Center, IFAS, Univ. of Florida, Quincy, FL, 1971-73; research technician and graduate research assistant, Texas A&M Univ., 1970-71; agricultural research technician, Entomol. Res. Div., ARS, USDA, College Station, TX, summer 1968; research technician, Texas A&M Univ., 1967-68; fieldman, Plains Pea Producers and Martin Produce, LaMesa, TX and Devine, TX, summer 1966; clerk in farm supply store,

Tri-county Farmer's Co-op, Devine, TX, 1964-66; cotton gin hand, C. E. Boyd and Devine Gin Co., Devine, TX, summer 1965; held other farm jobs prior to this period.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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Professor of Entomology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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Professor of Entomology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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March, 1976

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